Neurodevelopmental Disorders and Chiropractic: A Systematic Review of the Literature

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Abstract

**Objective:** To provide a comprehensive analysis of the current body of scientific literature regarding the chiropractic management of a wide variety of neurodevelopmental disorders.

**Methods:** A literature search was performed using PubMed, MANTIS, the Index to Chiropractic Literature, McCoy Press, Galileo, and ScienceDirect. Inclusion criteria consisted of full-text peer-reviewed articles written in English as they related to the efficacy of chiropractic management of neurodevelopmental disorders.

**Results:** 51 articles were selected. The results were: Three Randomized Controlled Trials (RCT), 7 Reviews of Literature, three Case Series, 34 Case Studies and three Survey/Commentaries.

**Conclusion:** There is a definite need for RCTs and subsequent systematic reviews of RCTs. Of research obtained in this study, the majority of articles dealt specifically with Autism Spectrum Disorder (ASD) and attention deficit disorder (ADD)/Attention Deficit Hyperactivity Disorder (ADHD) and were predominantly case studies. The chiropractic community should see this as a call to action to provide more substantive research regarding neurodevelopmental disorders.

**Key Terms:** Chiropractic, subluxation, pervasive developmental disorders (PDD), ADD, ADHD, learning disorders, sensory processing disorders, developmental delays, developmental, Epilepsy, Autism Spectrum Disorders, ASD, Bipolar

Introduction

**Definition**

Neurodevelopmental disorders are disabilities associated primarily with the functioning of the neurological system and brain. According to *Pediatric Chiropractic*\(^1\) these include but are not limited to Attention Deficit Disorder (ADD), Attention Deficit Hyperactivity Disorder (ADHD), learning disorders, sensory processing disorders, developmental delays, Cerebral Palsy (CP), mental retardation, epilepsy & seizure, Autism Spectrum Disorders (ASD) and Bipolar Disorder (BD). Possible etiologies for neurodevelopmental disorders involve environmental, biological and/or genetic factors.

It is important to note the etiology of neurodevelopmental disorders is not the focus of this review. Rather, we focus on the systematic review of literature and efficacy of chiropractic care for the treatment of neurodevelopmental disorders after manifestation and or proper medical diagnosis in children and young adults.
Incidence Rates for Neurodevelopmental Disorders

In 2000, it was estimated that one child in 150 was diagnosed with ASD, increasing to one child in 88 in 2008. The rates of diagnosis for ADHD have increased, on average, 3% each year from 1997 to 2006, increasing to an average of 5.5% from 2003 to 2007 and effects an estimated 8-12% of children worldwide. Prevalence of Cerebral Palsy has been reported as 3.6 in 3.6 per 1,000 in 1996 and 3.1 per 1,000 in 2000. There appears to be no indexed studies denoting the prevalence of tics in children. However, Lanzi et al. found the incidence of tic disorders among primary school students age 6-11 years in Pavia, Italy to be 2.9%. We have no basis to substantiate or refute this value; however, Lanzi et al. determined the prevalence to be uncommon. The most common learning disability reflected within the literature reviewed is dyslexia, and it has been shown to have a prevalence ranging from 5-10 per cent.

Chiropractic Care

With rising incidences of various neurodevelopmental disorders, the likelihood of healthcare professionals encountering them as a presenting complaint in their clinics is just as likely to rise. With chiropractors serving as portal of entry providers, it is also therefore likely that the practicing chiropractor will encounter such patients. It is therefore important to understand the possible relationship between chiropractic care and neurodevelopmental disorders.

The evidence presented within this literature review aims to demonstrate the plausibility of chiropractic care as an appropriate healthcare service utilized for neurodevelopmental disorders. Services provided include spinal adjustments focused on the correction of vertebral subluxation, improvement in joint function, reduction of pain, increased quality of life and levels of independence, as well as management of dizziness, proprioceptive and/or vestibular complaints, and possibly more.

Objective

The objective of this review of literature is to provide an analysis of the current body of scientific literature regarding the chiropractic management of neurodevelopmental disorders. The body of literature reviewed summarizes current areas of chiropractic management including but not limited to: patient specific population demographics, unique age-related care, utilization of services, co-morbidities and concomitant issues, preventative health measures, treatment considerations, opportunities for doctors of chiropractic regarding further clinical education and growth, standards of care, limitations and successes pertaining to existing research, as well as prospective research designs.

Due to the wide scope of this topic being investigated, it was not plausible, nor is it our intent, to determine the population numbers involved currently undergoing chiropractic care for neurodevelopmental disorders. Rather, we seek to determine, what, if any peer-reviewed literature exists to support the safety and efficacy of chiropractic care in these populations.

Methods

We performed a literature search using the following databases: PubMed, MANTIS, Index to Chiropractic Literature, McCoy Press, Galileo, and ScienceDirect. The initial search included the following key word ‘chiropractic’ joined separately to each of the following key words with the connector “AND”: ‘PDD’, ‘ADHD’, ‘learning disorders’, ‘sensory processing disorders’, ‘Developmental delays’, ‘cerebral palsy’, ‘mental retardation’, ‘retardation’, ‘dystrophy’, ‘autism spectrum disorder’, ‘ASD’ and ‘bipolar’. Initial inclusion criteria consisted of full-text peer-reviewed articles, written in English. Article abstracts were read to assess their inclusion based on whether the article reported on the efficacy of chiropractic care in the context of the previously defined list of neurodevelopmental disorders. Subsequently, a second literature search was performed by cross-referencing articles cited within the inclusion documents and those selected through the database search. New articles found were evaluated for inclusion based on whether the article reported on the efficacy of chiropractic care on neurodevelopmental disorders. Our systematic review of the literature revealed 51 articles that met our inclusion criteria. These consisted of three randomized controlled trials, seven reviews of literature, three case series, 34 case studies and three survey/commentaries.

Review of Literature

Randomized Controlled Trials (RCT)

Korshid et al. conducted a randomized clinical trial that assessed the effectiveness of Atlas Orthogonal (AO) upper cervical chiropractic care as opposed to full spine Diversified chiropractic care on children diagnosed with autism. Fourteen children participated in this study. All were originally under diversified care. Seven were randomly assigned to begin upper cervical care. AO was chosen because the instrument driven adjustment was more repeatable than by hand. The remaining seven continued with Diversified full spine technique. Pre- and post-x-ray analysis along with leg length inequality was monitored. Monthly reassessments were performed. The AO group used supine leg check and scanning palpation as objective findings, which indicated when to adjust. The AO group was adjusted up to twice per week as clinically indicated for three months. The ASD Treatment Evaluation Checklist (ATEC) was utilized to objectively measure the patients’ response to care. These authors concluded that AO was more clinically effective than that of Full Spine Diversified technique in their study sample. Both groups showed improvement in 6/7 participants; the AO group showed an average improvement of 32% whereas the Diversified group showed a 19% average improvement. It was noted that two children in the AO group were no longer classified as autistic after the course of care was rendered. The most common improvements were seen in communication, verbal, eye contact, mood, and physical sport skills. This study lasted five months. Although the authors did not list any limitations, some possibilities exist. The sample size was small, there was no blinding, and no long-term follow-up was performed to identify if post x-ray findings and ATEC scores persisted.
Karpouzis et al. performed a randomly controlled trial using Neuro Emotional Technique (NET) on children with ADHD. The goal of the study was to determine whether or not the NET protocol improved the clinical outcomes of ADHD. The study was ethics approved, interdisciplinary, controlled, double blinded, and randomized. The study was held in Australia. The inclusion criteria were being 5-12 years old, being diagnosed with ADHD by a medical doctor, psychiatrist, or physiologist, and were willing to sign the informed consent, and currently undergoing an intervention for the condition. Those included were split into three groups: A, B, and C. Three groups were blinded, and were not informed who would be receiving the adjustments, the sham adjustments, or the control. At the time of this investigation this article was only a design, and the study is ongoing. The conclusions will be disseminated in a later publication.

Bull illustrated the effects of Sunflower Therapy on 70 children. Sunflower Therapy is a method of making dyslexic children more attentive and feeling better. The methods used in Sunflower Therapy are supplementation, acupressure, spinal manipulation, and neuro-linguistic programming. Intervention methods are based on Applied Kinesiology. Each child went through eight, 40-minute sessions. The outcomes were measured using the Parenting Stress Index, and the Wechsler Intelligence Scale for Children. The author concluded that Sunflower Therapy was not effective at improving performance or making the children feel better. Only 22% of parents felt that sunflower therapy was effective. The limitations of the study are that the study was rather short, the compliance of the parents was in question and several modalities were being used.

**Literature Reviews**

Ferrance and Miller performed a review of the literature, which investigated existing chiropractic studies as they related to outcomes in patients with ADHD. They searched PubMed, Mantis, Index to Chiropractic Literature, and CINAHL databases for the keywords “attention deficit hyperactivity disorder”. They stated that the major limitation of their search was the low scientific value (case studies and case series) of their sources. While they admit that behavioral modification and screening for learning disorders should occur early in the evaluation and treatment of ADHD, they conclude that it is likely beyond the purview of most chiropractors. Additionally, psychostimulants are the most widely accepted effective treatment for ADHD, yet most chiropractors cannot, and would not, prescribe them. Despite a collection of case reports and case studies, the authors contest that there is no good evidence of the effectiveness of chiropractic manipulation for improving the symptoms of ADHD. They called for larger, more rigorous studies to be performed before any definite recommendations can be made.

Karpouzis et al. conducted a systematic review of the literature to determine the efficacy of chiropractic in terms of reduction of symptoms including, inattention, impulsivity, and hyperactivity for children and adolescents with ADHD. An article had to be full text and written in English to be included. Karpouzis et al. came up with 58 citations, 22 of which were clinical intervention studies. Only three out of 22 were pediatric or adolescent. No citations met the inclusion criteria. This study yielded an ‘empty review’. They determined that there was insufficient evidence to evaluate the efficacy of chiropractic care for the pediatric/adolescent patient with ADHD. The authors called for more research in this field. Limitations for this study included possibility for literature written in another language, publication bias, limited hard copy journals at the authors’ facility to search by hand, and unpublished literature from conferences was not looked for.

Alcantara et al. performed a systematic review of the literature on the chiropractic care of patients with ASD. They utilized 8 databases including MANTIS, ICL, PubMed, EMBASE, AMED, CINAHL, Alt-Health Watch and PsychINFO. Eligibility criteria for inclusion included: the study was a primary investigation/report published in an English peer-reviewed journal, the study involved patients under 18 years of age, and patients were diagnosed with ASD, Asperger’s Syndrome, Pervasive Developmental Disorder—Not Otherwise Specified (PDD-NOS). This revealed a total of five articles consisting of three case reports, one cohort study and one randomized comparison trial. The authors reviewed the epidemiology, diagnosis, pathophysiology and implications for chiropractic care. It was suggested that a trial of care should always follow the evidence-based model, but the literature was lacking on documenting the chiropractic care of children with ASD for both quantity and quality. This systematic review demonstrated need for more research to examine the safety and effectiveness of chiropractic spinal manipulation therapy and adjunctive therapies as they relate to ASD, Asperberger’s Syndrome and PDD-NOS.

Jennings and Barker authored a paper in 2006 discussing ASD from a chiropractic perspective. In the study the authors discussed some of the various approaches, causes, and interventions currently being investigated regarding ASD. The objective of the paper was to offer a systematic review of autism emphasizing elements pertinent to the manual therapist. The authors stated that the current body of literature fails to identify any anatomical, physiological or neurochemical cause for ASD. Various avenues of research included: the neurochemistry of ASD and its focus on serotonin, genetic approaches and their focus on the identification of inheritable factors for aspects of ASD, as well as family genetic studies that have documented the presence of a range of conditions and characteristics in the non-autistic relatives of individuals with ASD. Jennings and Barker stated that there is no medication known to cure ASD, nor are there any medications approved for use in the direct treatment of ASD. Regarding manual therapy and chiropractic interventions the authors stated that some researchers had discovered a laterality of the atlas in children with ASD and various suggestions had been made as to why removing upper cervical dysfunction may have a positive effect on the symptoms of ASD. As such, it was speculated that manipulation may help with some of the associated symptoms. There have been several anecdotal reports of chiropractors and other manipulative therapists seeing improvements in children with ASD. The authors reported on one study by Aguiar et al. in which a series of chiropractic adjustments on 26 autistic children over a 9-month period was conducted. In this study many of the children were taken off Ritalin, bladder and bowel control improved, some children started to speak, and
eye contact and attention span also improved. The authors included recommendations for treatment guidelines for children with ASD which included: establishing consistent treatment routines, avoiding any loud disturbances during treatment, distraction being the key, being alert for non-verbal cues of discomfort from the child, and also questioning parents about changes in behavior patterns. It is important to note that the authors also stated that case studies and anecdotal reports are encouraging, but further research in the form of larger, controlled trials are needed to establish the role of manipulative care in the treatment of ASD.

In 2001, Pistolese\textsuperscript{16} conducted a systematic review of literature regarding chiropractic care of children with epilepsy and seizure disorders. The objective of this review was to obtain the currently available chiropractic literature with regards to care of patients diagnosed with epilepsy with particular emphasis placed on children. The author assessed 17 articles and studies in which he discovered that 14 of the 17 studies reflected patients receiving anticonvulsant medications; which has been proven to be unsuccessful in the management of their condition. Of the studies reviewed, the author noted that 15 of the patients received upper cervical care in order to correct vertebral subluxations. Pistolese stated that it was important to evaluate the current literature with regard to the pediatric population with epileptic disorder; because out of the 125,000 new cases that develop each year, up to 50\% of those are in children and adolescents patient groups. Such statistics document the prevalence of epilepsy in patients under 18 as high as 4.7 per 1000. Each study examined each study for efficacy of care and the authors discovered that one study found that up to 73\% of families that consulted chiropractors noted benefits subsequent to treatment. Pistolese also noted that one area of significant insufficiency within the literature was the lack of appropriate classification and categorization of keywords and studies conducted. As such, the lack of appropriate and efficient categorization of scientific literature presents a challenge in gathering data in order to develop uniform formats, best practices and assess chiropractic interventions. The author did conclude that chiropractic care might represent a non-pharmaceutical health care approach for pediatric epileptic patients and may also be associated with a decrease in seizure activity. Pistolese further stated that the current anecdotal evidence suggested correction of upper cervical vertebral subluxation complex might be most beneficial.

Pauli\textsuperscript{17} performed a review of literature to describe current mainstream and alternative theories about learning disabilities especially focused on dyslexia and the effects of chiropractic care in people suffering from those conditions, and also to compare chiropractic causal theories to accepted medical models. The search yielded a total of 27 articles. Eight studies met their inclusion criteria. Four of them belonged to the lowest class of evidence while the other four were before or after studies. None of the studies met all of the predefined methodological criteria. The author concluded that all studies reviewed showed a positive effect of chiropractic care for individuals with learning disabilities and dyslexia, but various methodological weaknesses were present. There was no definitive conclusion in those studies, therefore all the studies were considered as preliminary. The author suggested that, within the limits of the studies reviewed, there seemed to be a potential role for chiropractic care to improve various cognitive modalities known to be essential for learning.

Gotlib and Rupert\textsuperscript{18} reviewed literature to determine the extent of new evidence related to the therapeutic application of manipulation for pediatric health conditions. Their search of literature was performed through both the indexed and non-indexed biomedical manual therapy literature. Their articles were classified upon the scale of evidence in hierarchy. The search yielded 1275 citations and 57 of them met the inclusion criteria from the relevant time period (January 2004 to June 2007). The composition of articles was 1 systematic review, 1 RCT, 2 observational studies, 36 descriptive case studies and 17 conference abstracts. The authors summarized that the evidence rests primarily with clinical experience, descriptive case studies and a select few observational and experimental studies. There has been no substantive shift in the body of knowledge during the past 3 \(\frac{1}{2}\) years. The limitations included the small sample sizes in RCTs and the fact that these studies were pilot or feasibility studies.

Case Series

Cuthbert and Barras\textsuperscript{19} discussed a case series of 157 children with developmental delay syndromes. The children in the study ranged in age from six to 13 years (86 boys and 71 girls). The children displayed difficulties with reading, learning, social interaction and school performance. The children were treated with applied kinesiology chiropractic technique. The outcomes of treatment were measured using a series of eight standardized psychometric tests, which evaluated 20 areas of cognitive function. All 157 children showed improvement from their pre-treatment tests to their post-treatment tests. The children displayed improvement in concentration, focus, attention, and ability to control impulsivity and their performance at home and school. Limitations of this study included lack of blinding and randomization of the subjects and testers.

Alcantara and Davis\textsuperscript{20} discussed four patients ranging from nine years of age to 13 years of age with medical diagnoses of ADHD who subsequent to their diagnosis, received chiropractic care for a minimum of five months augmented by nutritional supplements. The study was done as a retrospective case series. All four patients showed improvement using a 15-item parent/teacher ADHD questionnaire. Limitations of the study included the inherent limitation of making cause and effect inferences based on a study with a retrospective design such as this and the use of dual modalities of chiropractic and nutritional supplementation.

Boucher\textsuperscript{21} conducted a case series in which she performed a pilot study investigating the incidence of chiropractic care in learning disorders. This retrospective pilot study was performed in France, involving 10 children within a range of six to 16 years who received chiropractic care for a period of 12 months. Primitive reflex evaluation included the Moro reflex, asymmetric tonic neck reflex and spinal Gallant reflex for the presence of sustained primitive reflexes. Multiple chiropractic techniques were used including Logan Basic, Sacro-occipital Technique (SOT), Thompson, Pierce and various upper cervical techniques. While positive changes to
the treatment rendered was demonstrated following treatment, the changes associated with reduced retention of the primitive reflexes will be found over time measured in years.

The decrease of primitive reflexes to a level below expression and stabilization tended to occur around the 10th adjustment. Balance, posture and visual coordination also appear to have improved. By the 12th office visit the “retained primitive reflexes” progressively diminished to full extinction, their posture improved verticality in both sagittal and coronal planes, and visual coordination improved significantly. It appeared that chiropractic adjustments might have acted to contribute to proper neural function and maturation. Bouchet stated that chiropractic care might contribute to the normal postnatal development of the nervous system by facilitating specific connections from primitive to postural reflex. She stated the need for further study to be performed to determine which children with learning and developmental disorders may be best candidates for chiropractic care, since in these 10 cases the children were able to increase their potential and become more capable of being part of the learning process. This study is limited in that there was a small sample size (n=10) and it was retrospective.

Case Studies

Muir described the case of a five-year-old boy with ADHD. He was diagnosed one year before seeking chiropractic care after medical interventions failed in managing symptoms. Upon intake, the parents noted that the patient woke frequently during the night due to asthmatic symptoms but slept approximately 11-12 hours a night. He was delivered via cesarean section after an uncomplicated full-term pregnancy. Physical examination revealed motion restrictions, tenderness, hypertonicity and positive Kemp’s bilaterally from C2-C4 with pain and hypertonicity at the thoracolumbar junction. Treatment was given two to three times a week for six to eight weeks with a re-assessment at four and eight weeks from mid-June to the following May. Treatments included spinal manipulation, soft tissue work, and myofascial release. The patient’s parents noted decreased acting out and increased ability to follow instructions and home/school performance. The author concluded that there might be a role for chiropractic management of ADHD. Limitations include the use of subjective outcome assessment tools with a total lack of objective measures, a lack of criteria for diagnosis of ADHD, utilization of multiple interventions, and uncertainty as to whether the care improved symptoms or if the patient “grew” out of them.

Bastecki et al. described the case of a five-year-old patient diagnosed with ADHD by a general practitioner and subsequently treated with chiropractic care by Clinical Biomechanics of Posture (CBP) protocol. The patient was diagnosed with ADHD at age 2 by a medical doctor and treated unsuccessfully with pharmaceutics including Ritalin®, Adderall® and Haldol® for 3 years. The patient presented the chiropractic office and received 35 chiropractic treatments for 8 weeks by CBP protocol, which composed of mirror image adjustments, mirror image exercises and mirror image extension compression traction. After 27 visits, the child’s pediatrician stated that the patient no longer exhibited symptoms of ADHD. The outcomes showed a change from a 12 degree kyphosis at C2-C7 to 32 degree lordosis at C2-C7. Further, the child’s facial tics resolved and his behavior significantly improved. The medical doctor deemed the reduction in symptoms significant enough to discontinue medication. The authors concluded that there might be a possible connection between cervical kyphosis and ADHD, which may produce a desirable clinical outcome. Limitations included a possibility of spontaneous remission of ADHD, misdiagnosis by a medical doctor, and misreporting of improvement by parents. As this is a case report, further research is needed to determine the true effect.

Young documented the retrospective results of chiropractic treatment involving a five-year-old boy who had been diagnosed as suffering from ADHD, who also displayed other symptoms of developmental delay. The author noted symptoms which included speech delays, frequent temper tantrums, being easily distracted, poor short-term memory, aggressive behavior, dyspraxia, and also a tendency to be obsessive. It was reported that the patient attended a nursery school where the teachers found that he had very poor concentration, was unable to follow instructions, was aggressive towards the other children, spoke rarely and then only uttered single words which were indistinct. The author reported that the patient was generally clumsy, and at the time of his first visit had not yet achieved urinary continence. Of note regarding prenatal development; the mother consumed a moderate amount of alcohol and also smoked. Young reported that the chiropractic treatment included a combination of chiropractic adjustments, proprioceptive exercises, dietary changes and supplementation. Young found that over the course of chiropractic care all aspects of the child’s condition improved. The child’s mother, teachers and speech therapist also reported noted improvement in his language skills. The child received a total of ten chiropractic treatments over a two year period. Six treatments were done over a period of 12 weeks and the child was then placed on 4-monthly visits. Young stated that the specific chiropractic care consisted of adjustment to the atlas using an Activator instrument. Additionally, the patient was given proprioceptive exercises, which included balancing on his left leg, and was also placed on essential fatty acids and zinc supplementation. Following care, Young reports that the child now speaks clearly and fluently and also demonstrates marked decreases in aggressive tendencies and temper tantrums. This case study suggests that chiropractic care may have a positive effect on ADD and ADHD symptoms, but as a single study demonstrates the need for further investigation on the long-term effects of treatment.

Olaffson documented the changes in a 4 ½-year-old boy with a sensory processing disorder after chiropractic care. The case study suggested the boy likely had ADHD, reduced social interaction, and learning disabilities alongside the diagnosis of sensory processing disorder. The intervention included full spine adjusting and diet modifications, which included elimination gluten, refined sugar, and casein. The care was ongoing for 10 weeks. The outcomes of care were reduced social outbursts, dramatic increase in attention span, and the boy was able to read for the first time following the 8th adjustment. Olaffson concluded that this was a successful outcome following subluxation based care, but that more research should be done to clearly demonstrate the outcomes.
of children with developmental or learning disabilities.

A case report by Wolfertz and Dahlberg\(^2\)\(^6\) studied the effectiveness of the upper cervical chiropractic care of a patient with BD and ADHD. A sixteen-year-old male who suffered from BD and ADHD since six months of age presented for a chiropractic evaluation. His mother reported that the patient was born with the umbilical cord around the neck and forceps were used to assist the deliver. The medication used was once effective, but had become less so as of time of chiropractic examination. Pattern analysis was done by thermograph (Tytron-3000\(^3\)\(^M\)) and subsequent radiographs indicated a subluxation in the upper cervical region; Knee Chest Upper Cervical specific protocol was utilized to correct the identified subluxation. The outcomes were observed through the doctor’s findings, the mother’s subjective descriptions and the thermograph scans. After seven weeks of care, the patient’s symptoms were greatly diminished and no longer required any medication. Overall, during fifteen weeks of care, the patient and his mother reported resolution in his anxiety attacks, anger outbursts, irrational social interactions and general musculoskeletal pain. The authors concluded all symptoms were significantly decreased or eliminated by the Knee Chest Upper Cervical specific technique and stated more research is recommended to confirm the positive outcomes.

In a case study, Darragh and Blum\(^2\)\(^7\) discussed the resolution of ADHD under chiropractic care for a seven-year-old child. The patient was found to have pelvic torsion and fixations in the lower cervical and upper thoracic spine. The intervention in the study was a mirror-image toggle, upper anteriorities, and SOT blocking for the pelvic torsion. The patient was seen three times per week for one month, followed by two times per week for a month and a half. The result of care was improved posture, and improved behavior. As a result of chiropractic care, the child was removed from his regimen of anti-psychotropic medications by his psychiatrist and the child was reported to be functioning normally in social situations.

Cassista\(^2\)\(^8\) reported a case study of a child that was too hyperactive to remain in daycare. Chiropractic intervention may have decreased the symptoms of ADHD. Cassista described a case study of a child who was diagnosed with ADHD at two years old, and presented for care at four years. The management of this case consisted of adjusting the child three times per week for 2½ months. After 12 visits, the mother of the child reported that he was eating much better, and after 24 visits, the child’s asthma had also improved to the point that he no longer needed medications. Schoolwork improved, and “behavior became a non-issue.” After a two-month hiatus from care, the child’s previously restored lordotic curve became kyphotic, with the previous symptoms and behavior problems having returned. The author explained the importance of maintenance care after illustrating the regression of the child back into symptoms congruent with the initial presentation. There were few a limitations to the study; a normal child may encounter many traumas and other influences that may influence posture and symptoms, including dietary changes. Additionally, it is hard to fully determine that the lapse in care was the sole reason for the subsequent regression or purely coincidental.

Jaszewski and Sorbara\(^2\)\(^9\) reported on improvements made in a seven-year-old girl presenting with migraines, ADD, and scoliosis after using the Pierce Results System. The patient had right-sided facial paralysis as a result of a difficult birth. She underwent speech and occupational therapy to deal with speech, balance and coordination deficits. She also suffered from migraines three times a month since the age of two. Her ADD symptoms included aggressive behavior, cutting others in line, sporadic inappropriate behavior, and extreme impulsivity. She also presented with 8/10 pain in her low back, lumbar, and thoracic regions. Chiropractic evaluation demonstrated a hyperthermic zone in both the lumbar and pelvic regions. X-ray revealed an externally rotated right ilium and a thirteen degree scoliosis in the lumbar region. Videoflouroscopy revealed loss of motion at T1-3 and L2-5. The patient was seen once a week for five visits. Post treatment thermal scanning showed improvements after each visit. After the fifth visit, dramatic thermal improvements were noted, and prompted a follow-up x-ray, revealing a reduction of the scoliosis by eight degrees. According to the patient’s mother, ADD symptoms improved roughly 30 percent and migraines had resolved. After six months, the mother discontinued care for two years until symptoms reached original severity and repeated the same cycle a year later as well. The authors concluded that dramatic improvements were made and that further investigation into the effects of chiropractic on scoliosis, ADD, and migraines is warranted. Limitations included omission of any information about whether concomitant treatments were taking place at the same time as chiropractic care, lack of long-term follow-up and subjective evaluation by the mother.

Bedell\(^3\)\(^0\) presented a case of a seven-year-old female patient to emphasize the importance the role chiropractors may play in treatment of ADD. Management and care of the patient was performed using Torque Release Technique (TRT) for identification and treatment of the vertebral subluxations, subjective assessments performed by the mother (on a 1-worst to 10-best scale) on a weekly basis, and nutrition assessments with subsequent supplementation. Treatment lasted 90 days, with the mother noting improvement after three weeks of care. Through chiropractic care, the child was able to avoid the use of pharmaceutical drugs and was spared the stigma of being diagnosed clinically with ADD/ADHD. Despite the success of the case in the treatment through subluxation-based chiropractic care, the study was limited due to the fact that it was a case study and conclusions cannot be generalized to a larger population based on a single individual. The treatment protocol was multimodal using chiropractic adjustments, supplementation and dietary changes. Which treatment, if any, worked could not be identified. Furthermore, the mother's weekly assessments were subjective in nature. There is no description of any attempts to quantify the rating scale other than 1 (worst) and 10 (best), therefore, there are numerous biases that could have come into play.

Bloink\(^3\)\(^1\) discussed the chiropractic management of a 19-year-old female diagnosed with autism spectrum disorder (ASD) characterized by pervasive language delay. The patient was unable to speak prior to 11 years of age at which time she had a series of Tomatis Auditory Therapy (TAT) treatments in Belgium. By age 19 she could speak coherently, only with her neck in flexion and her eyes looking downward. The treatment
consisted of SOT and cranial care, specifically treatment for sacroiliac joint hypermobility syndrome (category two) and for a significant craniomandibular dysfunction (CMD). Immediately following care the patient was able to hold her head in a neutral position and clearly spoke, “Thank you very much, goodbye.” This result remained for approximately 7 days, however due to her significant CMD, it appeared she would need concurrent dental or orthodontic co-treatment to maintain a lasting positive result. Limitations include a small sample size and lack of controlled experimental design.

Marini and Marini discussed a case study of a 6-year-old boy with diagnosed Autism. He presented with reduced social interaction, altered behavioral patterns, language deficits, and learning difficulties. The child was previously diagnosed with Autism by a neurologist after magnetic resonance imaging ruled out brain pathology. The patient’s previous history included a vaginal birth assisted by epidural medication, bottle and formula fed during infancy, and all typical vaccinations up to date. The child was taking daily doses of Ritalin, and receiving speech therapy in school twice weekly. Prior to the initial examination, the mother was asked to fill out an Autism Treatment Evaluation Checklist (ATEC). Chiropractic examination diagnosed a subluxation pattern of a fixed posterior-inferior right ilium, a second thoracic vertebra was of posterior-left and second cervical spinous process was left of midline. Tense trapezii trigger points and spasms were noted on the right. The patient was adjusted using Diversified technique over a 16 week period. Improvement was noted after the fourth adjustment; the mother mentioned that the child no longer rocked his head and jabbered less. After his sixth adjustment, the child began spelling out words; something he had never done before. The mother reported that after seven weeks, the child began to vocalize his name, as well as the words that he had been spelling. By the twelfth week of care, the child was performing well in school. At this point the ATEC was re-administered to monitor progression. The ATEC is a one-page form designed to be completed by parents, teachers, or caretakers and scored out of 180 (lower scores indicate greater function). Speech/communication impairment improved from 16/28 to 9/28, sociability impairment reduced from 16/40 to 7/40, sensory/cognitive awareness improved from 15/36 to 6/36, and the health/physical behavior score reduced from 23/75 to 10/75. When all four scores are totaled, a reduction from 70/180 to 32/180 was observed; a 54.3% overall improvement, indicating mild severity. Limitations include a case study design with one participant and possible reporting bias.

McCormick discussed the behavioral improvements of a four-year-old autistic male child over six months of chiropractic care. The patient was diagnosed with autism at two years. His mother reported that his father smoked and she ate canned tuna almost every day throughout the pregnancy. The child hit early milestones within a normal time frame, but had difficulty communicating and making eye contact. He was also fully vaccinated with no noted change post-vaccination. Along with autism, the child had a history of gastrointestinal issues as well as a lack of toilet training. The doctor noted while performing the initial comprehensive chiropractic exam was challenging, but she found motion palpation restrictions at C2 and right sacroiliac joint. The patient’s mother was also given the ATEC to establish a baseline for possible improvement. The patient scored a 97, which put him in the lowest functioning group. Care was rendered sixteen times over twenty-four weeks, twice a week for four weeks, once a week for four weeks, once every two weeks for six weeks, and monthly for the remainder of care. During the course of care, no additional therapies were introduced. Within one week, the patient’s eye contact improved, he had willingly participated in new activities, and was happier. After two weeks of care, the patient was sleeping through the night and addressed his siblings by name without being prompted. After three weeks of care, the patient was more coordinated. After eight weeks, the patient was more aware of himself and his surroundings and the therapists and teachers working with him who were unaware of the chiropractic care being rendered noted an improvement in behavior. The ATEC was repeated after five months and showed only minor improvement at 90. The author concluded that chiropractic care plus the use of other integrative therapies can improve autistic behaviors. Limitations of this study include a focus on subjective outcome measurements with failure to demonstrate marked improvement objectively.

Hoffman and Russell reported on a ten-week case study which followed the subjective and objective outcomes of a three and a half year old autistic female receiving subluxation correction utilizing full spine Torque Release Technique. Adjustments were rendered using the Integrator® adjusting instrument. Significant objective improvements were seen on surface EMG throughout the course of care. The mother reported improved posture, spontaneity, expression of joy. She also reported a decrease in occurrence of nightmares, expressions of sadness, apparent discomfort, and hyperactivity. Limitations of this study include lack of objective measure of autism-associated symptoms and the nature of case report.

Zielinski and Borkhuis described a case that demonstrated the full resolution of symptoms of bilateral intermittent headaches, epilepsy, behavioral and developmental delay, acid reflux, sleep disturbances, and vomiting following the correction of vertebral subluxation in a 35-month-old female. The patient also showed significant improvements in ASD symptoms including: increased calm behavior, increased eye contact, happier demeanor, improved attitude, increased focus and attention and an initiation to sound out words. This study reported on the first 17 visits (240 days) of care. Thermography, motion palpation, spinal asymmetry, and muscle tone were used to analyze and detect vertebral subluxations. The activator adjustment instrument was utilized to deliver adjustments. The patient’s presentation continued to show improvements at the time of writing this report. Limitations of this study included the fact that, like most autistic children, this patient received care from a number of different providers and therapists.

Cohn described the case of a three-year-old male patient diagnosed with Pervasive Developmental Disorder and Sensory Processing Disorder. He experienced delays with communication skills, speech, cognitive function, motor skills, ambulation, social and emotional development, and adaptive and self-help skills. The patient was analyzes chiropractically using static palpation, surface electromyography and paraspinol thermography to determine the locations of
vertebral subluxations. Diversified adjustments were given to remove the identified subluxations. Over the course of ten months, the patient underwent treatment at a frequency of one visit per week. Significant improvements were noted including improved language skills, increased personal comfort, reduced bruxism, swaying and rocking ceased, and muscle tone was no longer an issue.

Scelfo and Chelenyak\(^{37}\) described the case of a nine-year-old male who presented with chronic ear infections, difficulty with social interactions and impairment of communication. The patient had previously been diagnosed with Pervasive Developmental Disorder initially and Autism subsequently. The patient was adjusted chiropractically using diversified and toggle-recoil techniques in addition to the administration of digestive enzymes by a nutritionist. The outcome was assessed using an ATEC. The ATEC improved by 16% overall with the Health/Physical Behavior aspect exhibiting the greatest increase which was 17%.

Rosen and Blum\(^{38}\) discussed chiropractic and SOT interventions used on a six-year-old male patient. In their study, Rosen and Blum discussed how chiropractic may be able to play a part in the treatment of autism spectrum disorders through the use of cranial techniques and SOT. In the study they reflect on the care of a six-year-old male patient who began care for several medically diagnosed conditions that had not responded to standard care. Initial complaints included: Asperger's syndrome, asthma, seasonal allergies, colds, severe allergies to mold, dust, animal dander and seasonal triggers. The authors noted that the standard medications for the patients Asperger's often made his asthma and allergy symptoms worse. The authors conducted a standard chiropractic, orthopedic and neurological exam as well as specific SOT spinal and cranial evaluations. The authors stated that the patient was initially treated as category two (sacroiliac joint hypermobility), which was stabilized within three weeks and corresponded with improvements of symptoms. By the second month the patient was treated as category one (sacroiliac joint fixation, pelvic torsion, and altered sacral nutation) and the cranial imbalances found began to resolve. The authors stated that the patient and family both reported that his Asperger's Syndrome symptoms began to settle down within the first week of care. As such, the authors inquire as to the temporal relationship between SOT spinal and cranial therapy in the patient's symptoms and activities of daily living. The authors discussed the positive reduction in symptoms following treatment as compared to the exacerbation of symptoms through prior treatment and/or medication. It should be noted that it is obviously difficult to extrapolate long-term consequences of treating such a patient population through one single case study. This single study demonstrates the need for additional research regarding chiropractic interventions, which include SOT spinal and cranial treatment for patients in the autism spectrum disorder classification.

Cleave et al.\(^{39}\) described two cases of individuals diagnosed with autism and their subsequent chiropractic care; one a 20 year old male, the other a 17-year-old female. Both patients lived in a specialized home for autistic children staffed with on location caregivers performing subjective observations during care. The patients were evaluated and adjusted using Activator Methods protocol for 20 visits over a span of 5 months. Caregivers reported positive observations early with successive improvement throughout the span of treatment. Observations included decrease in violent behavior to others and themselves. Patients appeared to be "calmed down" when frustrated, and with more normalized feeding behaviors. Limitations of the study are that these are two case files presented together, as such, aside from examples of positive outcomes of treatment; no further conclusions can be made. The authors mention both patients taking prescribed medications at onset of the case, yet fail to address or follow up on this aspect. It cannot be ruled out that the medications had no effect on the treatment. Caregivers were asked to observe the patients, and there is no clear description of this process. It could not be determined if the caregivers were qualified to provide accurate and unbiased observations. This case still serves to suggest that chiropractic care can have a positive effect on autism.

Drobbin and Woodruff\(^{40}\) reported on a case study of a seven-year-old girl who presented to a chiropractic office after being diagnosed by her pediatrician with a motor tic disorder of unknown etiology. Her tics began at the five years and progressively worsened over time. Upon observation and examination, the patient had a notable motor tic and vertebral subluxation located at C1 on the left, T6, and left pelvis. Palpation of the paraspinous muscles revealed hypertonicity along the right cervical and occipital region, which agreed with the patient’s posture appearing to have a right head tilt and elevated right shoulder from associated muscle contracture. The patient was adjusted one time per week using Thompson and Diversified technique. Observations of the patient’s motor tics were made at each visit. After her first adjustment it was reported that the patient was experiencing 25% less tics which continued for three days, with subsequent increase in tics occurring every 30 seconds. After the second adjustment the patient was having 50% less tics, with one tic occurring every minute. At this time, the patient’s mother stated that she rarely complained of neck discomfort. Following the third adjustment she was no longer experiencing motor tics. She also did not complain of any neck discomfort. The authors stated she is still under regular chiropractic care in which she was evaluated once per week, and remained motor tic free. Limitations of this case include a small sample size. Also no measurement data was performed at the time of the patient’s examination, suggesting that certain parameters could not be observed.

Stone-McCoy and Muhlencamp\(^{41}\) discussed a 20-year-old female that had experienced vocal and motor tics three years of age. Chiropractic examination revealed that the patient was found to have had subluxations at multiple levels, which were adjusted by hand and instrument. She was initially adjusted six times, and reported that headaches were gone by the 5\(^{th}\) visit, with tics decreasing at the 6\(^{th}\) visit. She was then coming in once per month, for wellness care. After a time of patient non-compliance, the tics worsened, and the patient returned under chiropractic care, being seen once per week for five months. The intensity of the tics went from the initial 8/10 to 3/10 (10 = worst), with concomitant headaches having ceased and she also reported less stress and tension. Overall, the patient was adjusted 32 times over the span of treatment. The authors concluded that with the positive outcomes of chiropractic care,
more research should be performed to further illustrate the positive effects of chiropractic care in people with motor or vocal tics. The limitations of this study were that there was a time of patient non-compliance, and the status of being a case study.

DeMaria et al.\textsuperscript{42} described the improvement in symptoms of an adolescent with Tourette’s syndrome under chiropractic care. A 14-year-old male presented with motor tics, migraine headaches and severe fatigue. The patient was experiencing 1000 violent motor tics a day and was medicated with Ibuprofen, Abilify and ORAP (pimozide) daily. Physical examinations were performed by thermograph and radiograph, with vertebral subluxations indicated at C6, C7 and T1. The patient was treated using the Pierce Results System over the course of 30 visits in 5 months. Outcomes suggested a dramatic reduction in the amount of tics daily; the total number was reduced from 1000 to 30-35 per day. The patient’s dependence on Ibuprofen was eliminated and his medical doctor reduced other medications. Even though the authors concluded chiropractic care utilizing the Pierce Results System resulted in subjective and objective improvements in a patient with Tourette’s syndrome, the possibility of spontaneous remission cannot be ruled out in a single case.

In their case report, Ferrucci et al.\textsuperscript{43} described a decrease in neurological symptoms following chiropractic care in a 45 year old male with Tourette’s syndrome, tardive dyskinesia, CREST syndrome, and fatigue. Subluxation correction was rendered utilizing Chiropractic BioPhysics (CBP) protocol. Improvements in posture and radiographic indicators of subluxation were also seen following treatment. Treatment lasted a 64 weeks. Interventions included CBP mirror image adjustments, exercises, and traction, during each visit. The patient also performed at home mirror image exercises. Limitations of this study include the failure to objectively measure reduction of neurological symptoms and the nature of being a case report.

McReynolds\textsuperscript{44} discussed a pediatric case where initial chiropractic care spanning several months was unsuccessful for reduction of tics. Initially, Diversified technique was used for 4 months, with subsequent switching to Activator Methods for "the next several months" before switching back to Diversified, still with an unsatisfactory response. Finally, it was determined to switch to focusing solely on upper cervical C1 (Atlas) care using the activator adjustment tool with Toggle Technique criteria. Resultant care with this method suggested in dramatic reduction in neurological tics as identified by tally sheets submitted by the parents on a weekly basis. Due to the transient nature of neurological tics it is difficult to determine if chiropractic care had any effect or if self-resolution was observed. This case did provide some evidence that supported the efficacy of chiropractic care, specifically upper cervical, on the reduction of neurological tics.

Alcantara and Adamek\textsuperscript{45} reported on successful chiropractic treatment of an adolescent patient with medically diagnosed conversion disorder. The patient was an 11-year-old female with complaints of uncontrollable tremors in both upper extremities and right lower extremity. The patient had previous consultations with a pediatrician, a neurologist and a psychiatrist. Physical examination, magnetic resonance imaging (MRI), computer axial tomography (CAT) scanning, blood analysis and electroencephalographic (EEG) studies all yielded negative results for an organic cause leading to the diagnosis of conversion disorder. The patient’s family indicated consultation with a chiropractor as a last resort before institutionalization. The chiropractic exam revealed difficulty walking unassisted, hypertonicity of spinal musculature, normal cervical range of motion, unremarkable orthopedic testing, cranial distortion, and subluxation at occiput, C1, C4, T4, T8 and sacrum. Chiropractic care included high velocity low amplitude adjustments and cranial-sacral dural pull maneuvers at cranial distortion regions. On the second visit after the cranial-sacral dural pull the patient completely ceased to tremor for approximately 15 min. At the third visit, the patient indicated a noticeable decrease in her tremors with respect to its intensity and frequency. At the fourth visit, the Logan Basic Technique was applied and the patient’s tremors completely ceased for 15 min. A stretching program was also instituted at this time to address hypertonic muscles. By the 6th visit, the patient’s large tremor movements had disappeared and replaced with mild twitches. Also at this time, the patient’s cranial-sacral system had balanced for the first time. Her tremors had ceased to be constant and by the 9th visit, only a mild twitch was noticeable. After 12 visits, the patient reported complete resolution of her symptoms. The authors postulated that the chiropractic adjustment produced an inhibitory reflex response that was segmental in origin and that this decrease of motor neuron activity lead not only to reduction of hypertonicity and the pathogenesis of pain but also a decrease in tremors.

Blum and Cuthbert\textsuperscript{46} discussed a two-year-old girl presenting for care with emotional and developmental delays. The patient was a fraternal twin birthed by caesarean section after her twin brother was born vaginally. Plagiocephaly was noted after birth. The patient’s mother stated that the patient experienced frequent bouts of rage, temper tantrums and nightmares which caused her to wake up screaming. She was also described as unfit for pre-school and unable to function at home in a family environment. Cranial evaluation revealed a left torsion and extension lesion of the sphenobasilar dural tissues with imbalances of the maxillae, occiput, frontal and left temporal bones. Cranial work and upper cervical care were rendered over five visits and a multi-mineral supplement was prescribed to help nervous system function. After the second visit, improved posture was noticeable. After the third visit, proprioceptive testing was negative and cranial bone respiratory function was significantly improved. After the fifth visit, it was stated that the patient was stable in both pre-school and family environments and she had stopped walking on her toes. The patient was followed-up with annually. The authors concluded that there is emerging evidence to support chiropractic care as a viable treatment option for developmental delay syndromes and believe it would be beneficial to find out how each subset responds to care and whether co-treatment should be considered. Limitations abound in this article as no outcome assessments were established when discussing the onset of care. The authors discussed improvements made, but never gave baseline information. Technique and follow-up strategies were not discussed in any sort of detail. The patient was also treated.
with supplementation so any improvements the authors claimed cannot be verified to chiropractic care alone.

Lerner and Lerner\(^4\) discussed the case of a four-year old male patient presenting with a history of a severe learning disorder and speech delay. The Pettibon System and manual diversified chiropractic adjustments were used to remove subluxations that were identified via palpation, thermography and radiographs. In addition, dietary modifications were applied in the form of removing sugar and grains from the child’s diet. After the first adjustment was given, the child immediately began speaking, putting together full sentences and recognition of his written name for the first time. The patient also improved to smiling and crying appropriately after initially presenting as emotionless. Like other studies, the effect of chiropractic in a case study cannot be verified when other concurrent treatments exist.

McCoy et al.\(^4\) conducted four retrospective case studies on four children with cerebral palsy. Their study evaluated paraspinal muscle tone, autonomic function, and changes and quality-of-life. The objective of the study was to review the literature and present the subsequent results experienced by these children who underwent chiropractic care to reduce vertebral subluxation. The four children had been previously diagnosed with cerebral palsy secondary to birthing trauma. According to McCoy et al., all demonstrated objective evidence of vertebral subluxation. The authors involved provided chiropractic care directed at reduction of subluxation. Measurements of paraspinal surface electromyography and thermography readings were taken prior to the initiation of care and approximately one month later. McCoy et al. found that all four children showed improvement in paraspinal muscle tone as well as a decrease in the number of levels of abnormal thermography readings. Further, all four children showed improvement in activities of daily living including mobility, feeding, and postural control. McCoy et al. concluded that these four patients undergoing chiropractic care for reduction of vertebral subluxation demonstrated improvement in muscle tone and autonomic function coupled with improvement in activities of daily living. The authors also discussed other research that reflected chiropractic interventions and changes within similar patient populations. These studies include research on a child with cerebral palsy treated by full spine chiropractic adjustments,\(^5\) a case report reviewed a 5 year old male with cerebral palsy undergoing upper cervical adjustment,\(^6\) a report on fifty children in a randomized controlled trial evaluating osteopathic manipulative therapy or acupuncture in children with spastic cerebral palsy, which reported that ninety six percent of parents reported some type of improvement from treatment of the children involved,\(^7\) a report on improvement in three cases of children who had disturbances in motor responses, postural development and infection undergoing manipulation of the atlanto-occipital joint,\(^8\) and also Biedermann’s,\(^9\) recommendations of manual therapy following a retrospective analysis of 114 infants with a multitude of complaints including delayed motor development. According to the authors, the review of literature reflected demonstrable improvement in quality of life, a decrease in dyspraxic activity and in all, except one, a decrease in dyssomnia. These reports are consistent with widespread anecdotal reports of similar types of improvements and are found to be consistent with other case reports in the literature. The authors state that given the significance of such types of improvements in the lives of these children a call for more extensive investigation of the effects of subluxation analysis and correction in children suffering from cerebral palsy is warranted.

Valente\(^10\) reported a case study with evidence of lifestyle improvements in a child with CP following chiropractic care. The patient was a 2 year old African American male adopted at birth along with his twin sister. The patient’s mother stated that he was diagnosed with hypotonic cerebral palsy as a result of traumatic birth, while his twin sister was diagnosed with spastic CP at the same time. The patient had many developmental delays due to CP and was not able to eat or swallow anything for several months after birth. The birth mother had a history of mental illness, diabetes and had given birth to 15 children, with the twins being children number 12 and 13. The child also suffered from seizures and gastroesophageal reflux disease (GERD). Chiropractic and physical examination revealed asymmetry of the occipital and parietal bones with a slight indentation of the cranial vault, restriction at the atlanto-occipital joint, restriction at T8 with hypertonicity of the musculature on the right from T6 through T10 and subluxation of the right sacroiliac (SI) joint. Neurological testing showed hyperactive reflexes (patella, Achilles and triceps), increased sensitivity to sensation and a positive Babinski. Toggle, Diversified and Activator techniques were used over the course of eight visits and a vestibular therapeutic swing was used as at-home treatment. After the first visit, the patient’s mother reported that her son had begun to pull himself up on his riding toys. By the fifth visit he started sleeping 9-10 hours at night, compared to 3-4 hours per night just 1 month prior. He also began walking without assistance. There was no change in head circumference, positive Babinski sign or hyper-active reflexes. Limitations include small sample size and a multitude of therapies used. It is also possible that the chiropractic care coincided with late development of the child.

Goodsell and Schneider\(^11\) reported a case study of a 16-year-old female patient with a history of CP who presented to the chiropractic office due to poor sleep habits and muscle spasticity. The patient had been born three months premature and had multiple congenital anomalies including a neural tube defect. She had been fed through a feeding tube and had a complete liquid diet since birth due to severe physical and cognitive impairments. Physical examinations were difficult to perform due to her spasticity and inability to ambulate or stand without assistance. Surface Electromyography and spinal thermography indicated subluxations at C1 and C7. The treatment was twice a week initially and a specific conservative chiropractic adjustment to correct vertebral subluxation was provided. After her sixth adjustment, the mother reported that the patient was sleeping normally without interruptions at night. Over six months of care, the patient showed a considerable decrease in sleep disturbance, muscle tone and decreased fixation at C1. The authors concluded that the correction of vertebral subluxation by chiropractic care caused improvements in sleeping condition and muscle tone. The patient and her family were able to return to a normal sleep schedule, which led to improved quality of life.
Cuthbert and Rosner\textsuperscript{56} presented a case report describing the chiropractic care of a 10-year-old boy with symptoms for developmental delay syndrome, asthma, and chronic head and neck pain. Chiropractic care using Applied Kinesiology with the use of manual muscle testing (MMT) was employed in treatment of the youth. Positive findings using MMT were used as a guide for interventions when weak muscles were moved toward strength. Treatment consisted of a diverse set of manual therapies to correct identified misalignments and insalivation (oral nutrient evaluation). The patient's symptoms all resolved and were still shown to be resolved 2 years post-treatment. Limitation to the study was that this was a single patient and it cannot be ruled out that the symptoms resolved on their own. Further, objective measures for asthma, reading test scores and headache pain diaries were not included. The patient was also continuing use of their asthma medication (previously unsuccessful) during care. There is no way to delineate whether the medication, chiropractic treatment, or a factor of both was most effective for reducing asthma symptoms.

Three children presented to two separate chiropractors with dyslexic symptoms. Young\textsuperscript{57} presented these cases to determine if there were any consistent factors during examination or history. All three children were treated using SOT (including cranial work). One chiropractor opted to include nutritional supplementation as part of their treatment protocol. The case series was compiled to determine plausibility for a pilot study exploring pre- and peri-natal trauma as a possible mechanism toward dyslexia. All children presented with co-morbidities of hearing deficit, balance difficulties, coordination issues, all experienced traumatic birth, were diagnosed with cranial faults and all three had history of a parent with at least dyslexic tendencies. All cases reported subjective improvement with linguistic skills, two of three showed improved balance and coordination. The very small case series provides only limited data, with minimal conclusions. Patients were self-selected by choosing a chiropractor for care. Therefore population bias is noted. It is unknown whether nutritional supplementation for one patient had any effect. Exact treatment of each patient is unknown other than technique used. Outcome of treatment was only subjective in nature. Future studies will need to develop objective criteria.

Elster\textsuperscript{58} discussed the use of upper cervical technique in the case of a 23-year-old male patient who developed rapid-cycling bipolar disorder and associated sleep disorder, seizure disorder, back pain, as well as migraine headaches. The patient developed all of these symptoms subsequent to an injury at age 17 during high school track meet when he landed on his head from a height while attempting to pole vault. Although this case is unique in regards to the patient not having any pre-existing symptoms prior to injury, it does demonstrate the resolution of neurodevelopmental issues such as diagnosed bipolar disorder and seizure disorder. Upper cervical technique was performed in order to correct and stabilize the patient's neck, and while under care assessed the patient at baseline, two months, and also four months to determine the patient's neurological status. The author noted after one month of care the patient reported an absence of seizures and manic episodes as well as improved sleep. After four months of care the patient maintained a decrease in seizures and manic episodes and also noted that his migraine headaches reduced from three per week to two per month. After 18 months from the initial visit the patient remained asymptomatic with a complete absence of all symptoms. This case demonstrates a possible link between the patient's initial trauma, the recorded upper cervical subluxation and his neurological and neurodevelopmental conditions. The author notes that the relationship between upper cervical subluxations and brainstem function is an area of much-needed research, and states that further investigation into upper cervical injury is needed. It is important to understand that this is a single retrospective case study reflecting improvements in one patient, and as such, has intrinsic limitations with regards to the efficacy and legitimacy of chiropractic care as an intervention.

Kuberus et al.\textsuperscript{59} discussed the case of an infant diagnosed with Down Syndrome (Trisomy 21) who received chiropractic adjustments and cranial sacral therapy. The patient initially presented with failure to gain weight and thrive as well as inability to breastfeed. The treatment administered consisted of full spine adjustments, cranial sacral therapy and kinesiotaping. The patient achieved her developmental milestones on the higher end of normal for Down’s Syndrome infants after a year of care. Her height and weight also normalized for an infant with Down’s Syndrome.

Leighton\textsuperscript{60} wrote an evidence-based case report on the case of a 15 week-old male that presented with non-synostotic deformational plagiocephaly (NSDP). He used this report as a platform to perform a systematic database search and critical review of best evidence to answer typical clinical questions that might arise in everyday practice regarding NSDP. His results yielded several systematic reviews, clinical guideline reports and cohort studies. Critical review of the articles generated an evidence-based approach to the chiropractic management of infantile plagiocephaly. The literature provided the best evidence to consider the aim and scope of treatment. A simple guideline approach to safe and effective chiropractic management of an infant with NSDP was established, based upon the best available evidence from the literature in conjunction with the pediatric training available to a chiropractor. The author searched the Cochrane databases as well as Highwire Press, Clinical Evidence (British Medical Journal Publications), National Library for Health (NHS) and the Centre for Evidence-Based Medicine website (www.cebm.net/index.asp) and the American Academy of Pediatrics. Finally, medical research databases were searched including MedLine, CINAH, PEDRO, Scopus, EMBASE, MANTIS, ICL, AMED, British Nursing Index, PsyctINFO, OSHROM, and Science Direct. Only English language papers dealing with infants aged 0—24 months were covered from January 1983 to December 2003. Leighton was unable to draw conclusions as to relative effectiveness of different treatment methods (active counterpositioning, dynamic orthotic cranioplasty, manual therapy) due to the low order of study designs, inconsistent outcome measures, and inconsistent protocols of therapy (age at initiation of intervention, duration of therapy, various combinations of multiple interventions), notwithstanding the inherent selection bias. He called for higher-order studies to be performed to elucidate the effects of manual therapies on NSDP.
Liow et al.61 conducted a survey to collect data on CAM use as pertained to epilepsy. 228 patients were surveyed either in person or via phone or mail. Patients whom completed the survey in person or by phone also had their files reviewed for additional data. File review was not completed for mail response as there were no patient identifiers. Inclusion criteria included: 18 years and up, and were physically able to speak, hear, or read. The survey consisted of 25 items concerning CAM use. Questions addressed usage, duration, adverse reactions, and patient’s perception of effectiveness. Demographics were also collected. Chiropractic ranked third most commonly used behind “Mega” vitamins, number two, and prayer/spirituality, number one. 19 reported use of chiropractic. Of those 21% reported benefit, while 42% reported no benefit. There was one single report of side effects following chiropractic; fatigue. This study found no significant relationship between CAM use and highest level of education. Limitations of this study can be found in the methodology used. Only face to face and phone collected additional valuable data. Mailers were only sent out once. A large percentage of the survey was not completed by 64%, which indicated it was unclear or too difficult. This survey was limited to patients in the Midwest.

Keils and Friedberg62 discussed the effects chiropractic has been able to show in the scientific literature when applied to children with ADD and ADHD. It was proposed that adjustments which focused in the upper cervical area could be the most appropriate chiropractic intervention for ADD and ADHD. The authors concluded that chiropractic was preliminarily supported as a safe and sensible solution to the problem of ADD and ADHD.

Gleberzon63 described the diagnostic criteria, etiology, prevalence and optimal management strategies available for children with autism, based on a review of the literature. The review was limited in that Gleberzon did not mention the inclusion criteria or the databases that were searched to gather the information for his review. With respect to the clinical management of autistic children, he determined that chiropractors should act as diagnostic gatekeepers. While it is reasonable for a child with autism to receive chiropractic care as part of a management strategy, a chiropractor ought to not simply substitute a preferred method of care that is alternative to the usual forms of care without sufficient evidence that the alternative care is more likely to result in better patient outcomes. He stated that it is not in the best interest of the child to manage their case using only manual therapies (manipulations). He recommends utilizing a chiropractic care plan on a clinical trial basis as a first approach.

Results

There are numerous approaches to evaluate published research. In order to rank the research evidence to better gauge what was available from our search, we decided to use the University of Oxford’s Centre for Evidence Based Medicine’s Levels of Evidence (March 2009)64 as our grading criteria. The criteria used five levels of evidence (High = Level 1 through Low = Level 5) with subsequent sub-classifications for Levels 1 through 3 assigned a subsequent letter within each level (High = subclass ‘a’ through Low = subclass ‘c’). A Systematic Review of RCTs would warrant a Level 1a grade, whereas an expert opinion paper would be the lowest at Level 5. For a full, in depth description and criteria used, please visit the website cited in the references section.

There is a definite lack of what would be considered high levels of research identified in our search (Table 1, 2). We found only three studies considered to be high levels of research for RCTs (level 1b),3-10, 64 one of which has yet to publish their findings.3 The study by Korshid et al.6 suggested improvement using both AO and Diversified full spine technique, but lacked a control, had no blinding and suffered from a small sample size. So while promising, the study is inherently limited. The study from Bull10 utilized Sunflower Therapy which consisted of multiple treatment modalities, spinal manipulation being only a single one. While Bull recruited 70 participants, this study was limited by the number of modalities and questionable compliance of the parents. Furthermore, the author concluded that Sunflower Therapy was not effective in improving patient performance.

Seven reviews of literature were reviewed.11-14,16-18 In all seven articles the authors concluded that the chiropractic literature was nearly void of higher levels of research and that the bulk of the research available consisted of anecdotal evidence from case files (considered the lowest class of evidence).

Three case series (Table 2)19-21 suggested positive outcomes. Two of the case series had low participant sample size20,21 whereas Cuthbert and Barras19 utilized 157 children, but failed to include blinding and randomization despite showing improvement in all participants between pre- and post-treatments.

We included 34 case studies and three surveys/commentaries as part of our review. While these are considered low levels of evidence (level 4),65 case studies are critical to the chiropractic profession. Back in 1997, DeSouza65 noted that the field of physiotherapy had a “paucity” of literature to support the profession, further noting that physiotherapists “seem reluctant to write about their work.” He also questioned why even case work was not published when even medical journals describe clinical casework.65 Chiropractic research appears to have much in common with the field of physiotherapy as described by DeSouza. Chiropractic research involving higher levels of evidence is clearly lacking. Case files are the “bread-and-butter” of the chiropractic profession (just like in physiotherapy) because they highlight work done by clinicians on actual patients. Through case files, we can see a diverse set of clinical skills being applied to actual patients with the subsequent results. This in turn can build a set of evidence that can be used to lay the foundation for larger, and better designed studies.66 Summed up, case files provide clinical reality which focuses on the individual patient that lead investigators toward more sophisticated studies.66 Case reports have also been credited with making major advances in the fields of medicine.67 This latter fact should not go unnoticed for a health care profession with such a paucity of research as chiropractic.

We would like to think our literature search was complete and
Discussion

As demonstrated herein, neurodevelopmental disorders are not a single entity but rather a series of disorders each with their own etiology, pathophysiology and treatment standard protocol. We have included the definition of neurodevelopmental disorder from Anrig and Plaugher as it is seemed appropriate to view them from a chiropractic perspective. A subsequent definition from the United States Environmental Protection Agency defines neurodevelopmental disorders as, “...disabilities associated primarily with the functioning of the neurological system and brain. Examples of neurodevelopmental disorders in children include attention-deficit/hyperactivity disorder (ADHD), autism, learning disabilities, intellectual disability (also known as mental retardation), conduct disorders, cerebral palsy, and impairments in vision and hearing. Children with neurodevelopmental disorders can experience difficulties with language and speech, motor skills, behavior, memory, learning, or other neurological functions.”

As we can see, both sources are very much compatible with one another. For the purposes of this review, we used the definition provided by Anrig and Plaugher.

It appears evident to us that when discussing neurodevelopmental disorders and chiropractic care, the bulk of the research done has been with ASD and ADHD, mainly through case files. Our search revealed that the predominant neurodevelopmental disorders associated with chiropractic care were ADHD and ASD.

Treatment and diagnosis of these disorders can frequently be difficult. Very often a combination of professional therapies and providers, medical pharmaceuticals as well as home and school-based programs is required to effectively treat the array of neurodevelopmental disorders discussed herein. As we have seen, chiropractic care is but one option.

Chiropractic care is considered to be a CAM service with chiropractors having been identified as the most established provider of CAM in North America. With respect to ASD there appears to be little in the way of evidence to support the use of pharmacological interventions and treatment. Perhaps this is why the use of complementary and alternative forms of treatment are on the rise for ASD in children. Parents are becoming more concerned with safety and the side effects of prescribed medications and seem to be embracing the use of CAM. It is therefore logical to make the assumption that parents will be concerned about prescribed medications for any sort of neurodevelopmental disorders. The use of CAM therapies has increased with 7 out of 10 people in the post-baby boomer population reporting some type of CAM therapy by 33 years. One study reported that of patients seeing a medical doctor, 79% perceived the combination CAM in association with a medical doctor to be superior to either one alone, and 15% reported seeing a CAM provider prior to medical services. Chiropractors and conventional health care providers should therefore be aware of a rising interest from the public on alternative methods for treating children who exhibit neurodevelopmental disorders and be able to discuss available options with them.

The cost to treat developmental disorders vary by diagnosis, therefore, it is not easy to provide an annual combined cost of all neurodevelopmental disorders. Recent evidence does suggest that previous estimated costs were substantially underestimated. It has been suggested that even a minor improvement in the performance of neurodevelopmental disorder patients would be of great significance to the patients, parents and society as a whole. This idea seemingly drives researchers to look for pharmaceutical approaches to treating the various disorders. Casten et al. suggested reactivation of neural plasticity in patients since it is instrumental in the repair of the human brain.

Evidence in the form of case files has numerous accounts suggesting possible positive outcomes from patients undergoing chiropractic care with the various neurodevelopmental disorders. The chiropractic profession has long espoused that treatment of the vertebral subluxation complex (VSC) has had a positive effect on a variety of detrimental health conditions. Through a review of literature, the existence of the VSC can be objectively measured. How might chiropractic adjustments account for positive outcomes seen in the published literature? One mechanism may be through neuroplasticity of the central nervous system. Evidence suggests that abnormal sensory input into the brain of rats alters the physical anatomy of the brain. These results have also been seen in humans. In fact, brain gray matter volume was significantly correlated with nerve conduction velocity measurements in carpal tunnel syndrome patients; this could provide an easily accessible method of objectively measuring neuroplastic changes without having to resort to advanced diagnostic exams like magnetic resonance imaging. Baroncelli et al. was able to reproduce the effects of earlier studies by demonstrating the recovery of amblyopia in rats through neural plasticity using environmental enrichment strategies. Seminowicz et al. also presented evidence suggesting that abnormal brain anatomy was reversed after successful treatment of low back pain. Such stimuli could have implications for other nervous system disorders with Baroncelli et al. specifically suggesting efficacious alteration to Rett’s syndrome, Down’s syndrome and Alzheimer’s disease; all of which are disorders of the neurological system. Cervical spine manipulation has already been implicated in alterations of cortical somatosensory processing as a mechanism for pain reduction. It has also been implicated that the high-velocity, low-amplitude chiropractic thrust has been responsible for neuroplastic changes and may also affect the cortical brain and deeper functions. If the VSC causes abnormal nerve signaling, and the abnormal nerve signaling, using pain as an example, can...
cause neuroplastic changes in the central nervous system, and subsequent removal of abnormal signals allowing for plastic changes back to the norm, then it stands to reason that the VSC could be implicated in neurodevelopmental disorders. Thus, management of the VSC could have a positive effect for those persons suffering from a wide variety of neurodevelopmental disorders. While the exact mechanism through which chiropractic treatment of the VSC might work is not yet known, we cannot ignore its plausibility.

It is generally accepted that there are two main schools of thought within the chiropractic profession. One focuses on treatment of vertebral subluxations and is often labeled as "straight" chiropractic. The other is labeled as "mixer" chiropractic, which focuses on a broader scope of practice to include a larger list of musculoskeletal complaints. Regardless of the chiropractic labeling, in an effort to support the validity of chiropractic treatment of the vertebral subluxation, the Council on Chiropractic Practice (CCP) was established in 1995.2 In order to fulfill their mission, the CCP formed a multidisciplinary panel of representatives to analyze the available research data on vertebral subluxations, and evaluate the available studies and evidence. To that end, the CCP published the Council on Chiropractic Practice Clinical Practice Guideline Number 1, Vertebral Subluxation in Chiropractic Practice in 1998; now in its fourth edition.3

According to CCP Guidelines, the care of children for subluxation with chiropractic is "accepted as appropriate for use in chiropractic practice" based on evidential support in the form of expert opinion based on clinical experience, individual case studies and basic science rationale. Further, literature support in the form of multiple case studies, pre- and post-studies, and observational and validity studies also justifies the use of subluxation based chiropractic care. Likewise, the duration of subluxation based care is also established according to the guidelines based on the same level of support. The guidelines further identify that while chiropractic is not a treatment for behavioral or mental issues, it has been established as a "clinical strategy that may improve the clinical status of persons with general health issues and certain behavioral or mental health conditions." We further contend that with regards to the latter statement, neurodevelopmental disorders can manifest themselves in ways that be seen as behavioral or mental health conditions such as those seen in ASD, ADD/ADHD or bipolar disorders.

While chiropractic does not traditionally treat neurodevelopmental disorders, they do treat the vertebral subluxation which is defined as,

"a neurological imbalance or distortion in the body associated with adverse psychological responses and/or structural changes, which may become persistent and progressive. The most frequent site for the chiropractic correction of the subluxation is the vertebral column."4

The subluxation is very much established within the realm of chiropractic treatment and removal, or treatment of the VSC may very well improve those persons suffering from neurodevelopmental disorders.

**Conclusion**

The current body of scientific literature pertaining to the chiropractic management of neurodevelopmental disorders reflects a significant lack of prospective and gold standard studies of a higher level of research. There is a definite need for RCTs and subsequent systematic reviews of RCTs. Of the research obtained in this study, the majority dealt specifically with ASD and ADHD. Additionally, two of the three RCTs were dominated by ASD and ADHD. This signifies a distinct lack of research into a broad topic that includes other subcategories of neurodevelopmental disorders. The research identified herein was predominantly case studies, which accounted for 73% (Table 1) of all studies reported. It is evident that the chiropractic profession is lacking in high-level research on the topic of neurodevelopmental disorders. As such, the chiropractic community should see this as a call to action in order to provide more substantive research pertaining to interventions, treatments and techniques, best practices, standards of care, as well as collaborative and interdisciplinary efforts.

If we consider the new research that shows chiropractic adjustments having a direct effect on neural plasticity of the central nervous system8 and other research linking abnormal stimuli to plastic changes within the central nervous system along with the case studies herein which show associated benefits from chiropractic treatment with regards to neurodevelopmental disorders. The mechanism by which this could happen appears plausible. Further advances in neural plasticity research may yet reveal stronger connections to chiropractic treatment.

Studies by Pauc and Pauc and Young were able to recruit 100 children with neurodevelopmental disorders from a chiropractic clinic. This suggests to us that there already is a significant number of parents bringing their children for chiropractic care. If their care was not beneficial we would expect that such studies would be required to recruit candidates from multiple clinics. The publication of more case studies showing positive results of chiropractic subluxation based treatment on persons, especially children, with neurodevelopmental disorders is definitely warranted in order to create a more solid foundation for stronger and higher levels of clinical research.

Considering the goal of a subluxation based chiropractor to treat the VSC, its safety with regards to children based on the CCP Guidelines, and not treating neurodevelopmental disorders specifically, along with the results shown herein with regards to the available case files, we believe there is enough evidence to support the use of chiropractic treatment on children who have been previously diagnosed with neurodevelopmental disorders, especially ASD and ADD/ADHD. We suggest a conservative treatment approach that would focus specifically on diagnosed subluxations within the vertebral column and co-management with other medical professionals to better objectively quantify any changes that may manifest in the presentation of the patient’s neurodevelopmental disorders, which would then add additional strength to the case for future consideration into publication as a case file.
Acknowledgements

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<table>
<thead>
<tr>
<th>Study Type</th>
<th>Percentage</th>
<th>Number</th>
<th>Evidence Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random Controlled Trial</td>
<td>9%</td>
<td>5</td>
<td>2b</td>
</tr>
<tr>
<td>Literature Review</td>
<td>13%</td>
<td>7</td>
<td>3b</td>
</tr>
<tr>
<td>Case Series</td>
<td>6%</td>
<td>3</td>
<td>3b</td>
</tr>
<tr>
<td>Cohort Studies</td>
<td>2%</td>
<td>1</td>
<td>3b</td>
</tr>
<tr>
<td>Case files/Commentaries</td>
<td>70%</td>
<td>37</td>
<td>4</td>
</tr>
</tbody>
</table>
Table 2 Summary of High (2b) and Moderate (3b) levels of literature

<table>
<thead>
<tr>
<th>Authors</th>
<th>Participants</th>
<th>Technique(s)</th>
<th>Disorder(s)</th>
<th>Evidence Level</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Randomized Controlled Trials (RCT)</strong></td>
<td></td>
<td></td>
<td></td>
<td>2b</td>
<td></td>
</tr>
<tr>
<td>Korshid et al. 8</td>
<td>n = 14</td>
<td>AO, DFS</td>
<td>ASD</td>
<td>AO group showed an average improvement of 32% whereas the DFS group showed a 19% average improvement</td>
<td></td>
</tr>
<tr>
<td>Karpouzis et al. 9</td>
<td>unknown</td>
<td>NET</td>
<td>ADHD</td>
<td></td>
<td>Data not yet published</td>
</tr>
<tr>
<td>Bull 10</td>
<td>n = 70</td>
<td>SMT, AK</td>
<td>Dyslexia</td>
<td>Author concluded therapy was ineffective</td>
<td></td>
</tr>
<tr>
<td><strong>Literature Reviews</strong></td>
<td></td>
<td></td>
<td></td>
<td>3b</td>
<td></td>
</tr>
<tr>
<td>Ferrance and Miller 11</td>
<td>na</td>
<td>na</td>
<td>ADHD</td>
<td>No good evidence to support effectiveness of chiropractic manipulation</td>
<td></td>
</tr>
<tr>
<td>Karpouzis et al. 12</td>
<td>adolescents</td>
<td>na</td>
<td>ADHD</td>
<td>Study yielded an 'empty review' based on search criteria</td>
<td></td>
</tr>
<tr>
<td>Alcantara et al. 13</td>
<td>&lt; 18 years</td>
<td>na</td>
<td>ASD, Asp, PDD</td>
<td>Total of 5 articles; conclusion for more research needed</td>
<td></td>
</tr>
<tr>
<td>Jennings and Barker 14</td>
<td>na</td>
<td>na</td>
<td>ASD</td>
<td>Evidence from case studies encouraging; larger controlled trials needed to establish role of manipulative care in treatment of ASD.</td>
<td></td>
</tr>
<tr>
<td>Pistolese 16</td>
<td>children</td>
<td>na</td>
<td>Epilepsy</td>
<td>Anecdotal evidence suggested correction of upper cervical subluxation complex might be beneficial</td>
<td></td>
</tr>
<tr>
<td>Pauli 17</td>
<td>na</td>
<td>na</td>
<td>Dyslexia</td>
<td>No definitive conclusion could be made, but there seemed to be a role for chiropractic care</td>
<td></td>
</tr>
<tr>
<td>Gotlib and Rupert 18</td>
<td>na</td>
<td>na</td>
<td>various</td>
<td>Evidence rested primarily in the form of clinical expertise and case studies</td>
<td></td>
</tr>
<tr>
<td><strong>Case Series</strong></td>
<td></td>
<td></td>
<td></td>
<td>3b</td>
<td></td>
</tr>
<tr>
<td>Cuthbert and Barras 19</td>
<td>n = 157</td>
<td>AK</td>
<td>DDS</td>
<td>All 157 children showed improvements from their pre- and post-treatment tests.</td>
<td></td>
</tr>
<tr>
<td>Alcantara and Davis 20</td>
<td>n = 4</td>
<td>SMT</td>
<td>ADHD</td>
<td>All 4 children showed improvement</td>
<td></td>
</tr>
<tr>
<td>Bouchet 21</td>
<td>n = 10</td>
<td>LB, SOT, Th, PRS, UC</td>
<td>Learning Disorders</td>
<td>Possible decrease in primitive reflexes</td>
<td></td>
</tr>
</tbody>
</table>

ADD-Attention Deficit Disorder; ADHD-Attention Deficit Hyperactivity Disorder; DDS-Developmental delay syndrome; ASD-Autism Spectrum Disorder; Asp-Asperger’s Syndrome; OCD-Obsessive Compulsive Disorder