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Retrospective review of case records of school-aged children receiving chiropractic care

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ABSTRACT

Background: Chiropractic care is utilized in school aged children for a variety of health complaints, including headaches, postural issues, nocturnal enuresis, neurodevelopmental disorders, and back pain. Chiropractic care, with its ability to impact sensorimotor integration, motor control and the prefrontal cortex, could therefore potentially benefit school aged children.

Methods: In this retrospective case series, records of patients presenting for chiropractic care at an onsite school chiropractic clinic were reviewed. Patients underwent 12 weeks of chiropractic care and completed three questionnaires and two sets of neurophysiological scans. The data from these questionnaires and scans were combined, averaged, and statistically analyzed.

Results: One hundred and eighty records of children aged 5–18 years from nine schools were included in the overall analyses. Statistically significant improvements were noted in the 'health and activities' sub-section and overall score of the Pediatric Quality of Life Inventory™ and in the hyperactivity domain of the Strengths and Difficulties questionnaire.

Conclusion: This retrospective review of case records from children attending an onsite school chiropractic clinic has demonstrated some changes in health-related quality of life following a period of 12 weeks of chiropractic care. Further research using a clinical trial design is needed to extrapolate the findings and to assess causation.

1. Introduction

Childhood is a period of huge growth and development. The health and experiences of children during this critical time can have long-term impacts on disease rates, mental health, and overall well-being for the rest of their lives(Drozdz et al., 2021; Goodman et al., 2011; Middlebrooks., 2007; Marcus et al., 2022; Bellis et al., 2019). However, the health and wellbeing of children today is showing some alarming areas of decline and concern (Lebrun-Harris et al., 2022). Data from the National Survey of Children's health in the US from 2016 to 2020 showed an increase in rates of anxiety, depression, behavioral disorders, and obesity (Lebrun-Harris et al., 2022). The survey also showed declining rates of preventative medical visits, daily physical activity, and parents mental health (Lebrun-Harris et al., 2022). The decline in key areas of health is also evident from more historical data from the 2007 and 2011/2012 National Survey of Children's Health(Initiative et al., 2024) which showed higher rates in many of the domains related to good health (preventative medical visits, physical activity) and lower rates of obesity, suggesting that the decline in key areas of children's health has been evident for nearly two decades.

The US department of Health and Human services' Healthy People 2030 campaign have numerous strategies related to children's health,

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however many of these domains are also showing a decline in progress (Promotion et al., 2024). Concerningly, areas such as overall mortality rates in children, levels of physical activity and participation in sport, school performance in reading and math and death from child abuse are getting worse (Promotion et al., 2024). Only a few domains, such as oral health, are improving (Promotion et al., 2024).

There is also an increasing number of neurodevelopmental disorders (NDD's) seen in school-aged children (Francé et al., 2022). Neurodevelopmental disorders (NDD's) encompass conditions such as autism spectrum disorder (ASD), dyslexia, attention-deficit hyperactivity disorder (ADHD), dyspraxia, dyscalculia, dysphonia, Tourette syndrome, synesthesia, and other distinctions in behavior and neurobiology (Francé et al., 2022). Global prevalence of NDD's can be difficult to ascertain due to varying capabilities in the detection and diagnosis of these conditions and the true prevalence is thought to be higher than the current detection rates. The current prevalence is estimated to be 15% of school-aged children, with ADHD having the highest prevalence at 5–11% (Francé et al., 2022). This prevalence is increasing with current data from the 2022–2023 National Survey of Children's Health showing 10.5% of the population age 3–17 years in the US currently have ADD or ADHD, in 2011/2012 the prevalence was 8%(Initiative et al., 2024).

These conditions are associated with several health and wellbeing difficulties, including poor sleep, poor school performance, gross motor function deficits, musculoskeletal pain, headaches, digestive issues, and other physical health complaints (Abdelgadir et al., 2018; Donaghy et al., 2023; Alabaf et al., 2019; Blackmer et al., 2016; Boivin et al., 2015; Gnanavel et al., 2019; King-Dowling et al., 2019; Landgren et al., 2023). The pathophysiology of many neurodivergent and neurodevelopmental conditions are often unknown, and specific diagnoses are based on clinical observations using criteria from The Diagnostic and Statistical Manual of Mental Disorders (Association., 2013).

It is clear from recent evidence that there is an increasing incidence of certain health complaints and disorders in school-age children. There are numerous campaigns and strategies that are being employed by the US department for Health and Human Services. However, there is also a growing interest in the use of complementary and alternative health medicine (CAM) in the paediatric population. Utilization of CAM was recorded at approximately 12% in 4–17-year-old children in the 2012 National Health Interview Survey in the US (Black et al., 2015). The most frequently used modality is dietary supplements (nonvitamin, nonmineral), followed by chiropractic or osteopathic manipulation (Black et al., 2015).

Chiropractic, a health care modality focusing on spine function and motion to improve central neural function, suggests that areas of joint dysfunction, or vertebral subluxations, may negatively alter sensory input to the brain, impacting the central nervous system's (CNS) ability to self-regulate, self-organize, adapt, repair and heal (Haavik et al., 2012, 2021; Lelic et al., 2016; Taylor et al., 2010). When not corrected, over time these changes can lead to symptoms of dysfunction and pain and lessen the ability of the CNS to adapt and respond to internal and external environmental cues (Haavik et al., 2021).

Chiropractic adjustments, also known as spinal manipulation, target joints with altered alignment and/or mobility that result in aberrant afferent feedback to the CNS (Haavik et al., 2021). Over the past two decades, growing evidence has indicated that chiropractic care can influence sensorimotor and multimodal integration, enhancing the accuracy of brain schemas related to the inner body and external environment in neurotypical populations (Haavik et al., 2011, 2012, 2016, 2021; Lelic et al., 2016; Taylor et al., 2010; Baarb et al., 2018; Christiansen et al., 2018; Holt et al., 2016, 2019; Niazi et al., 2015). It is now known that chiropractic adjustments in adults have a neural plastic effect on the brain and have been shown to have a particular influence on the prefrontal cortex, an area of the brain that is responsible for executive functions, such as memory, goal planning and focus (Haavik et al., 2021; Lelic et al., 2016; Taylor et al., 2010).

Chiropractic care is a frequently utilized health care modality amongst the paediatric population around the world (Gotlib et al., 2008; Marchand, 2012). Parents and caregivers seek alternative therapies for their children for a variety of reasons but often it is related to back or neck pain, concerns over medication side effects, a lack of improvement with traditional therapies or wanting to seek a natural approach (Blackmer et al., 2016; Guinchat et al., 2020). The most common reason for seeking chiropractic care in the paediatric population is musculoskeletal complaints (Marchand, 2012; Ndetan et al., 2012; Peng et al., 2021). Previous research on chiropractic care in the paediatric population has also shown improvements in quality of life and a high satisfaction of care (Alcantara et al., 2020). Chiropractic care for children has been used in the clinical setting to help co-manage individuals with NDD's, particularly autism spectrum disorders, ADHD, and other behavioral disorders (Alcantara et al., 2010, 2011; Strand et al., 2019; Fairest et al., 2019; Shaw et al., 2021; Parnell Prevost et al., 2019). There are numerous case reports and some basic science studies that have investigated the effects of chiropractic care on various NDD's (Alcantara et al., 2010, 2011; Strand et al., 2019; Fairest et al., 2019; Shaw et al., 2021; Parnell Prevost et al., 2019). The current available literature suggests that some individual children with NDD's appear to show improvement following chiropractic care. Changes reported, that may be due to chiropractic care, include improved concentration, motor control, reading, sleep, and behavior (Gotlib et al., 2008; Alcantara et al., 2010, 2011; Strand et al., 2019; Fairest et al., 2019; Shaw et al., 2021). However, larger clinical studies are lacking, thus further research is needed to understand causality and to confirm these individual observations.

The purpose of this study is to review the case records of children receiving chiropractic care in a school setting and to investigate possible neurophysiological and health-related quality of life (HRQOL) changes.

2. Materials and methods

This study was a retrospective case series design that reviewed case records of children who received 12-weeks of chiropractic care in a school setting. This study was ethically approved by the Institutional Review Board (IRB) of Life University, Marietta, Georgia, USA (Ethics number: *removed for deidentification)*.

2.1. Sample

The population sample for this case series was children aged 5–18 years attending a public school in the United States. The case records were provided by a private chiropractic practice run by two chiropractors who provide chiropractic care at the participants' schools.

Children were offered chiropractic care if they were identified by teachers/educators as having an NDD, or if requested by the child's caregivers due to musculoskeletal and/or other health complaints. The chiropractors providing the care assessed and screened the children for eligibility to receive chiropractic care, and as part of standard clinic protocol, consent for use of de-identified data in a research study was obtained.

Case records were reviewed from the year 2021. For this case review all records from children who met the following inclusion criteria were

included- 1) completed 12 weeks of chiropractic care, and 2) had received chiropractic care at one of the participating schools in the district. There were no other specific exclusion criteria.

2.2. Intervention

Chiropractic care was provided to the students in one of the nine schools of the school district. The children attended the chiropractic sessions at the school where they were enrolled. The chiropractors are both very experienced in chiropractic care for school-aged children and have provided chiropractic care to students within their district for several years. The chiropractic care was provided by the same two chiropractors and unchanged throughout the study period. Children attended weekly chiropractic care sessions for 12 weeks (once a week). Each session was approximately 5 min in length. They also attended an initial assessment (assessments described below) for about 30 min and another follow-up assessment at the end of the 12 weeks of care in line with the usual care practices of the chiropractors.

Chiropractic care sessions were comprised of a brief discussion with the child and caregiver to gain usual clinical information and assent/consent from both. Chiropractic care was then delivered by registered chiropractors from the chiropractic team. This involved an assessment of the entire spine to identify areas of vertebral subluxation (i.e., spinal dysfunction). This assessment involves identifying reduced intersegmental motion, reduced joint play, altered muscle tone of the paraspinal muscles, tenderness to touch and segmental oedema, which are all common signs of vertebral segmental dysfunction (Triano et al., 2013). Chiropractic spinal adjustments were then applied to the identified areas of dysfunction using modified Diversified, Logan Basic and Activator® techniques (modified depending on the child's age, build, and comfort as is common practice). These manual techniques are commonly used in chiropractic care and involve the application of a specific high-velocity, low amplitude thrust to the dysfunctional spinal segment. The activator instrument, a hand-held device that delivers fast, precise, and low-force thrusts, was also used when deemed necessary.

2.3. Outcome measures

Several clinical and neurophysiological outcome measures were recorded by the chiropractors at baseline, and at the completion of the 12-weeks of chiropractic care. These outcome measures included three different questionnaires and two different scans measuring various elements of neurological function, all part of usual chiropractic care for this clinic.

2.3.1. Questionnaires

Participants were required to fill out questionnaires about their quality of life, mental health, school, and peer relationships. The chiropractors use validated PROMs for these school aged children as appropriate, including the Strengths and Difficulties Questionnaire (SDQ) (Lebrun-Harris et al., 2022), the Pediatric Quality of Life Inventory (PedsQL™) Measurement model (Initiative et al., 2024) and the Patient Reported Outcomes Measurement Information System (PROMIS) Pediatric-25 (Promotion et al., 2024; Francé et al., 2022).

The SDQ is a brief questionnaire used to assess and screen for behavior and mental health problems in youth. It has been widely used around the world both in a clinical setting and for research purposes. The SDQ assesses five different domains—emotional symptoms, conduct problems, hyperactivity/inattention, prosocial behavior, and peer relationship problems (Goodman et al., 2009). It has been assessed has having good psychometric properties and is particularly good at detecting conduct, hyperactivity, depressive and some anxiety disorders (Brann et al., 2018; Silva et al., 2015; Woerner et al., 2004). There are different questionnaires for different age groups (2–4, 4–10, 11–17 years). Scoring is done based on answering statements using a 3-point scale with options of not true, somewhat true and certainly true.

The PedsQL™ measures HRQOL in children and can used in various populations, including those with NDDs (Varni et al., 2005, 2006; Bastiaansen et al., 2004). It assesses four generic core scales—physical functioning, emotional functioning, social functioning and school functioning (Varni et al., 2005). Scores are based on a 5-point scale that asks 'how much of a problem is this for you' for various tasks/activities with options of never, almost never, sometimes, often, and almost always. This questionnaire is filled out by the child and can be used from ages 2–18 with different questionnaires for different age groups (Varni et al., 2005). The questionnaires used in this study were the different child self-reports for ages 5–7, 8–12 and 13–18.

The PROMIS-25 is a paediatric self-report that assesses five general health domains—physical function, pain, fatigue, emotional health, and social health. This questionnaire has been utilized in various chronic health conditions to assess quality of life and health outcomes but was developed as a general or non-disease specific scale (Cox et al., 2020; DeWalt et al., 2015; Hinds et al., 2019). Various studies have analyzed the psychometric properties of the individual components of the questionnaire with good reliability and validity outcomes (Cox et al., 2020; DeWalt et al., 2013, 2015; Hinds et al., 2019; Bevans et al., 2018; Lai et al., 2013). Children aged 8–17 years fill out the self-report and for children aged 5–7 years the form is filled out by a parent-proxy.

2.3.2. Scans

The children also had two non-invasive scans performed that measure various neurophysiological functions. These scans were comprised of spinal thermography measurements recorded over the paraspinal muscles, and a 3-min photoplethysmography (PPG) recording. All scans were recorded using the INSiGHT Scanning technologies (CLA Inc., Toronto, Ontario, Canada).

The thermal scans involve the participant being seated and having a roller device run gently over the muscles on either side of the cervical spine and lumbar spine. The thermal device recorded the surface temperature of the skin using bilateral thermocouples positioned a few millimeters from the skin to measure differential temperature. Skin temperature is determined by the flow of blood through the cutaneous blood vessels, which is regulated via the sympathetic nervous system through the vasoconstriction of these vessels (Gunnar and Wallin, 1990). These thermography scans were a surrogate measure of autonomic nervous system (ANS) function and are commonly used in chiropractic spinal assessments (Triano et al., 2013; McCoy et al., 2011; Owens et al., 2004). Resting thermography recordings were taken bilaterally and averaged at the 1st, 3rd, 5th, and 7th cervical vertebral level, lumbar vertebral levels 1, 3, 5, and the 1st sacral level.

Finally, PPG required the participant to sit quietly for a 5-min recording period with the fingers of one hand resting on a device which sensed the pulse. PPG is an optical technique used to detect volumetric changes in blood in the peripheral circulation which can be used to derive pulse-rate variability (PRV) (Dehkordi et al., 2013). In children at rest, PRV has been found to be highly correlated with heart rate variability (HRV) (Dehkordi et al., 2013), a metric used extensively in health research to assess the function of the parasympathetic nervous system (Berntson et al., 1997; McCraty et al., 2015).

2.4. Data analysis

All the data from the patient case records was compiled by the chiropractors providing care to the children. This included detailed patient demographics, PRO scores and PRV metrics were compiled into an Excel spreadsheet. Regular detailed clinical history, subjective and objective data was also noted from each chiropractic appointment by the chiropractor. All data was de-identified using a numerical code for each patient prior to being sent for data analysis to a trained scientist with several years of experience an independent data analyst.The statistical procedure was performed in R software (version 4.0.4, Vienna, AT) using lme4 package version 1.1.26 (Team., 2013). Only fully completed questionnaires were used in analysis and any responses with missing data were not used. Descriptive statistics such as unadjusted means, standard deviations, and counts were used to describe the baseline characteristics of the data, and Shapiro-Wilk tests were computed to assessed for normality. Repeated measured mixed model regressions using the lme4 package (Bates, 2016) were used to assess for differences in outcomes between pre- and post-chiropractic intervention. Fixed effects were group, time (Time: pre or post intervention), and the random effects were participants. Paraspinal skin thermography was analyzed using a generalized linear mixed-effects model from the lme4 package (Bates, 2016). Estimated marginal means of each group pre and post intervention were calculated using the emmeans package (Searle et al., 1980). Pairwise differences with adjusted p-values between pre and post for each group were also calculated with the emmeans package. Repeated measured mixed model results were reported as (coefficient, [95% confidence interval], p-value) and generalized linear mixed-effects model as (ratio, [95% confidence interval], p-value) (Zuur et al., 2016). Statistical significance was defined as p-values less than 0.05 adjusted using Holm multiplicity correction as appropriate (Aickin et al., 1996). All data were presented at two or three significant digits for ease of reading, but all calculations were performed with unrounded data.

3. Results

Records from one hundred and eighty children (mean age: 10.4 ± 9.9 years, 37.9% female) from 9 schools in a particular district were included in this case series. Children presented with a variety of complaints including headaches, nocturnal enuresis, poor posture and various NDDs. Patient demographics are shown in Table 1. Not all children had a formal diagnosis but were identified by the parents or teachers as having learning and behavioral difficulties or musculoskeletal complaints and referred in for the chiropractic care. All conditions relating to the musculoskeletal system were grouped together under that umbrella term. This included headaches, back pain, poor posture or similar complaints. Some data sets were incomplete, see results below, as students were not always attending school. The average student attendance was 87.5% during 2021. Children had an average of 10.3 ± 3.2 adjustments and the techniques used were manual Diversified (89.5% sessions), Activator Methods® (1.6% sessions), Logan Basic (no sessions used this technique solely), or a combination of all three (8.9% sessions).

Table 1
Participant demographic information of 180 school aged children.

Age range	5–18 years
Age mean ± SD years	10.4 ± 9.9
Male:Female ratio	2:1
Clinical/Behavioural presentations:	
Musculoskeletal	51
Anxiety	36
Behavioural disorder	31
Learning difficulties	21
ADHD	20
ASD	12
Nocturnal enuresis	9

3.1. Pediatric Quality of Life Inventory™ (PedsQL™)

The total PedsQL™ score was significantly improved after the chiropractic intervention (average of 12.4) compared to what they scored prior to starting chiropractic care (average of 14.5) ($t(217) = 3.25$, $p < .001$, see Table 2). The effect size for this difference is 0.18 (Cohen's d). The children's 'health and activities' subdomain scores showed a significant improvement post-chiropractic, reducing to an average of 4.1 compared to an average of 5.0 at the beginning of care ($t(1260) = 2.83$, $p = .005$). The effect size for this difference is 0.25 (Cohen's d). Nineteen participants had incomplete data sets so were not included in this analysis. Scores for feelings, getting along, and school subdomains were not significant pre-to post-chiropractic care ($p > .05$).

3.2. Strengths and disabilities questionnaire (SDQ)

There was a significant reduction in the subdomain 'hyperactivity' scores pre- (5.72 ± 2.89) to post-chiropractic care 5.30 ± 2.98, 0.42, [0.09, 0.75], $p = .013$, Table 3). This difference had an effect size of 0.14 (Cohen's *d*). Scores for the remaining subsections, i.e. 'emotional', 'conduct', 'peer relationship', 'prosocial', and 'total score domains' were not significantly different after chiropractic care ($p > .05$). Forty-six children's data sets were not able to be included in this analysis due to incomplete data sets.

Table 3
Results for the Strengths and Disabilities Questionnaire (SDQ) pre- and post-chiropractic care.

	Pre-chiro	Post-Chiro	coefficient, [95% CI], *p*-value
n	134	134	
Emotional	1.95 (2.07)	1.93 (2.29)	0.02, [-0.25, 0.30], 0.872
Conduct	1.70 (2.17)	1.70 (1.96)	0.00, [-0.23, 0.23], 0.999
Hyperactivity	**5.72 (2.89)**	**5.30 (2.98)**	**0.42, [0.09, 0.75], 0.013**[a]
Peer	2.21 (2.03)	2.07 (1.95)	0.13, [-0.08, 0.34], 0.217
Prosocial	6.66 (2.51)	6.90 (2.51)	−0.24, [-0.59, 0.11], 0.179
Total	11.56 (6.45)	11.00 (6.32)	0.56, [-0.10, 1.22], 0.097

Note-all domain scores are out of 10, total is out of 50, and a higher score indicates greater difficulty in that area.
[a] Indicates a significant result.

Table 2
The PedsQL™ scores pre- and post-chiropractic care.

	Pre Chiro	Post Chiro	coefficient, [95% CI], *p*-value
n	161	161	
Health & Activities (out of 20) mean(SD)	**4.99 (4.37)**	**4.07 (3.72)**	**0.92, [0.28, 1.57], 0.005**[a]
Feelings (out of 16) mean(SD)	4.91 (3.94)	4.6 (3.78)	0.31, [0.335, 0.93], 0.335
Getting along (out of 12) mean(SD)	3.36 (3.01)	3.23 (3.22)	0.14, [-0.25, 0.52], 0.479
School mean (out of 12) (SD)	5.07 (3.18)	4.96 (3.29)	0.11, [-0.40, 0.62], 0.675
Total mean (out of 60) (SD)	**14.5 (11.87)**	**12.39 (11.47)**	**2.11, [0.97, 3.25], <0.001**[a]

Note- A higher score indicates the child has more difficulty with the task/domain.
[a] Indicates a significant change.

3.3. Patient-reported outcomes measurement information system pediatric profile 25 (PROMIS-ped-25)

For a small subset of children (n = 31) pre- and post-chiropractic intervention PROMIS-25 data was collected. There were no significant findings for any of the PROMIS-Ped-25 domains ($p > .05$).

3.4. Heart rate variability (HRV)

HRV (measured in beats per minute) was analyzed for time and frequency domains in the areas of high frequency, low frequency, inter-beat intervals, total power and high-to low frequency ratio and given an overall HRV score. There were no differences in any of these metrics post-chiropractic intervention ($p > .05$).

3.5. Thermography

Thermography was analyzed by difference in degrees centigrade bilaterally over the spine. There were no significant findings for thermography at any of the spinal levels assessed ($p > .05$).

4. Discussion

This retrospective case series in 180 children revealed statistically significant improvements following 12 weeks of chiropractic care in several areas. Notably, statistically significant improvements were observed in the health and activity domain and overall score of the PedsQL™ questionnaire, reflecting enhanced self-reported quality of life related to health and activities. Additionally, significant improvements in the SDQ's hyperactivity domain were evident following the chiropractic care. These positive changes highlight the potential benefits of chiropractic care in addressing certain aspects of well-being and behavior of school-age children. However, as this is a case series, it is not possible to infer causality.

Improvements in quality of life in children under chiropractic care has also been reported previously. A study published in 2020 reported an improved quality of life in children receiving chiropractic care measured by the PROMIS parent-proxy short forms(Alcantara et al., 2020). The results showed statistically significant improvements were seen in all the quality of life domains measured-anxiety, depression, fatigue, pain interference, physical function mobility and peer relationships(Alcantara et al., 2020). Only a small number of children completed the PROMIS-25 questionnaire in this case series and the findings were not significant, potentially due to the small sample size. The effect sizes for the statistically significant changes seen in this study (PedsQL health and activity domain and total scores, SDQ hyperactivity domain) are considered to be very small to small according to the Cohen's classification(Cohen, 2013). This suggests a potential clinically significant result, as even a small effect in health-related quality of life or in children struggling with hyperactivity can be important. A larger sample size in a study with a more rigorous research design, such as a clinical trial, may yield more information on the clinical significance of the effects on quality of life.

The were no significant changes in the PPG scans (i.e., HRV) nor the thermography scans. Previous studies on the effects of chiropractic care on HRV in adults have reported that HVLA spinal adjustments (also known as manipulation) have had significant improvements on HRV parameters (Borges et al., 2018; Haas et al., 2017; Win et al., 2015). Some of these studies have found alterations in the lower frequency bands and the lower frequency to higher frequency ratio (Borges et al., 2018; Win et al., 2015). However, with more recent understanding of the interpretation of heart rate variability data it is difficult to interpret such changes (Hayano et al., 2019; Laborde et al., 2017). Heart rate variability analysis is complex and can fluctuate during the day and between days. Further research needs to be done on these aspects of HRV to adequately determine the effects of chiropractic care on autonomic nervous system activity, especially in children.

While research into the effects of chiropractic care for school-aged children or those with neurodevelopmental disorders is in its early stages, studies in adults have shown improvements in mental rotation tasks (Baarbe et al., 2016), handgrip strength (Fenton., 2018), whole-body reaction times (Humphries et al., 2013), visual attention tasks and gaze stability (Cade, 2023), and improved joint position perception (Haavik et al., 2021). These benefits are thought to arise from the adjustments' ability to modulate neural activity by reducing aberrant sensory input to the brain, thereby resetting dysfunctional brain circuits, and facilitating the return to a more normal physiological state (Haavik et al., 2021). Spinal adjustments offer a therapeutic intervention capable of improving spinal function by directly influencing the neurophysiological mechanisms underlying vertebral subluxations (joint dysfunction) (Haavik et al., 2021). Effective and functional sensorimotor integration is vital for motor control and learning new movement skills (Farid et al., 2017). Previous studies have indicated that chiropractic care may enhance sensorimotor integration, allowing the brain to better respond to internal and external environments (Haavik et al., 2012, 2021; Lelic et al., 2016; Holt et al., 2016). This improvement may contribute to the enhanced learning and behavioral regulation reported by some children in this study during their period of chiropractic care. It may also be possible that correcting vertebral subluxations could have contributed to the changes seen in hyperactivity and quality of life for children in this study. However, this is a relationship that requires further research.

4.1. Strengths and limitations

This retrospective review of case records of school aged children receiving chiropractic care is a large case series that adds to the growing body of literature exploring the effects of chiropractic care in the pediatric population. There is currently a paucity of evidence for the effectiveness of chiropractic care in the pediatric population, and whilst this study is not a clinical trial it does offer some insight into potential benefits of chiropractic care for school-aged children, the ability to provide care for children in a school setting and ideas for future research. Another strength of this study is the use of neurophysiological measurements and quality of life measurements which attempts to capture the different aspects of the potential effects of chiropractic care.

As a restrospective case series there are also inherent biases and limiatations that must be acknowledged. These include relying on documented findings, the inability to collect missing data, no randomisation or blinding and no control group. The recording of physiological data, such as PRV, was conducted in a school environment, which may have introduced background noise or distractions that could affect the accuracy of the recordings. Measures were taken to limit this by having a quiet setting and recordings done at similar times of the day each time.

Autonomic nervous system function was assessed in this study using PPG scans to measure HRV and thermography to measure skin temperature regulation, but these methods have their limitations. PPG scans are useful as a non-invasive method of capturing HRV and thus can be used to interpret some aspects of ANS function, however they do not capture a full picture of the ANS(Liu et al., 2021). Subtle changes in sympathetic and parasympathetic activity can be missed, as well as complex vascular responses involving deeper arteries. In regard to thermography, this assesses skin temperature regulation, which can indirectly assess ANS function due to the role of the sympathetic nerves in regulating blood flow(Ootsuka et al., 2015). However, it has its limitations as it can be influenced by other causes of skin temperature changes, such as ambient temperature, skin health and inflammation. Studies assessing the validity of thermography in detecting vertebral subluxations are not conclusive(Triano et al., 2013), so using this as a tool to detect change in spinal health over time in this group of children may be limited.

The type and number of chiropractic adjustments that the children

received is also a limitation. Chiropractic care in this trial, was provided with the intention of correcting vertebral subluxation, i.e. segments of the spine that are not functioning in a healthy manner (Haavik et al., 2010). The attending chiropractors would assess and adjust these children when and where necessary, in an individualized, pragmatic approach. This introduces some variability, that may be the reason for no significant changes in the thermography scans for example. One child may have received adjustments at the 8th thoracic vertebrae, while another at the second cervical spinal level. Averaging out changes at each spinal level may therefore have been clinically meaningless. At the same time, the fact that the chiropractors adjusted the children according to each child's spinal needs can also be considered a strength of the study, helping to increase its external validity. However, the lack of intervention standardization may have reduced internal validity.

As this is a case series it is not designed to judge effectiveness of an intervention. This means that based on this case series alone it is not possible to know whether the chiropractic care resulted in the improvements noted by the children, or whether there were other confounding variables responsible for the noted changes. However, this case series suggests it would be worth conducting a randomized controlled trial in this population to determine whether it is the chiropractic care that is responsible for the positive outcomes.

5. Conclusions

This retrospective review of case records from children attending an onsite school chiropractic clinic has demonstrated some changes in health-related quality of life following a period of 12 weeks of chiropractic care. As this is a case series, it is not possible to claim causation. Further research using a clinical trial design is needed to extrapolate the findings and to assess the causality of chiropractic care. Insights from this study contribute to the growing understanding of how chiropractic care may positively affect health and wellbeing in school-aged children.

CRediT authorship contribution statement

Jenna Duehr: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Conceptualization. **Lona Cook:** Software, Funding acquisition, Data curation, Conceptualization. **Amanda Blonigen:** Software, Resources, Methodology, Funding acquisition, Data curation, Conceptualization. **Alice Cade:** Writing – review & editing, Writing – original draft, Formal analysis. **Tanja Glucina:** Writing – review & editing, Writing – original draft. **Monika Buerger:** Writing – review & editing, Conceptualization. **Stephanie Sullivan:** Writing – review & editing, Methodology. **Tyson Perez:** Writing – review & editing, Validation, Methodology, Formal analysis. **Muhammed Samran Navid:** Validation, Software, Methodology, Formal analysis. **Imran Khan Niazi:** Writing – review & editing, Validation, Software, Resources, Methodology, Funding acquisition, Data curation, Conceptualization. **Heidi Haavik:** Writing – review & editing, Supervision, Conceptualization.

Informed consent statement

Informed consent was obtained from all subjects involved in the study.

Institutional Review Board statement

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board (IRB) of Life University, Marietta, Georgia, USA.

Data availability statement

The data is not publicly available because of ethics committee restrictions.

Disclosure statement

The authors declare no conflicts of interest.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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