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Christie Kwon Date

Secondary analysis of a dataset to estimate the prevalence of vertebral subluxation and its implications for health promotion and prevention

By

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Degree to be awarded: Master of Public Health

Prevention Science

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By

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D.C., Life University, 2011
M.S., Johns Hopkins University, 2005
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An abstract of
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2020

Abstract

Secondary analysis of a dataset to estimate the prevalence of vertebral subluxation and its implications for health promotion and prevention.

By Christie Kwon

Objective Vertebral subluxation (VS) is a clinical entity defined as the misalignment of the spine affecting biomechanical and neurological function. The identification and correction of VS is the primary focus of the chiropractic profession. The purpose of this study is to estimate the prevalence of VS using a sample of individuals presenting for chiropractic care and to explore the public health implications.

Methods A brief review of the literature was conducted to support an operational definition for VS that incorporated neurologic and kinesiologic exam components. A retrospective, quantitative analysis of a multi-clinic dataset was then performed using this operational definition. Patient demographic data included age, gender, and past health history characteristics. In addition to estimating overall prevalence of VS, age- and gender-stratified estimates in the different clinics were calculated to allow for potential variations.

Results A total of 1,851 patient records from 7 chiropractic clinics in 4 states were obtained. The mean age of patients was 43.48 (SD = 16.8, range: 18-91 years). There were more females (n = 927, 64.6%) than males presented for chiropractic care. Patients reported various spinal or extremity pain, numbness, or tingling; headaches; ear, nose, and throat-related issues; visceral symptoms; mental health concerns; neurocognitive issues; and concerns about general health as well as overall wellness as their reasons for seeking chiropractic care. The overall prevalence was 78.55% (95% CI: 76.68-80.42). Female and male prevalence were 77.17% and 80.15%, respectively; notably, all per-clinic, age, or gender-stratified prevalence were ≥ 50%.

Conclusion Albeit nonrandom, the sample has a broad geographic distribution. The results of this study suggest a high rate of prevalence of VS in a sample of individuals who sought chiropractic care. Further investigation into the epidemiology of vertebral subluxation and its role in health promotion and prevention is warranted.

Keywords: *vertebral subluxation, chiropractic, epidemiology, prevalence, prevention science*

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Chapter 1: Introduction

Background & Theoretical Framework

Established in 1895, the chiropractic profession continues to explore the establishment of an operational definition of the vertebral subluxation (VS) that is evidence-based. Vertebral subluxation is defined by chiropractors as misalignment of the spine affecting biomechanical and neurological function; both body systems must be involved (Kent, 1996). The spinal column houses and protects the spinal cord and nerve roots. According to Gray's Anatomy, "the nervous system controls and coordinates all organs and structures of the human body" (Standring S. & Gray, 2008).

Although the assessment and correction of vertebral subluxation are the basis of chiropractic, there is a lack of gold standard within the profession of what constitutes VS (Russell, 2019). The term subluxation and its neurological consequences have been explored in the chiropractic and medical literature for centuries (Kent, 1996). The VS model was strengthened in the 1980s and 90s as the neurological and physiological effects of biomechanical misalignment were further studied (Senzon, 2018). In this same period of time, multiple models of VS have been developed, and controversies over the operational definition of VS have since ensued. Despite a lack of agreement on the best direct measurements to evaluate for subluxation, research has demonstrated that a number of methods of detection are reliable, valid, and could be incorporated into an operational definition for VS (Russell, 2019).

An operational definition clarifies the criteria for assessing a problem. The operational definition is a concrete description of a construct in terms of the variables, procedures, actions, or processes by which it could be measured or observed (APA Dictionary of Psychology, 2020). Adoption of an operational definition of vertebral subluxation is necessary to support scientific

knowledge and coherent understanding of the criteria to determine whether a person is subluxated. Moreover, the selection of an appropriate operational definition affects the validity of subsequent prevalence calculations. Biomechanical assessment is commonly conducted by measurement on plain film radiograph, but neurological components are measured by a variety of valid tests. Various reliable exam findings suggest neurological disruption, such as;

- Inflammation of the C2 (second cervical vertebra) Dorsal Root Ganglion (DRG),
- Positive Fakuda Step test,
- Leg Length Inequality,
- Tautness of the erector spinae muscles, or
- Upper extremity muscle weakness

Presence of any of these findings, coupled with misalignment of vertebrae as determined by x-ray analysis, are directly indicative of vertebral subluxation and will be considered as the operational definition for the purpose of study. This supposition is consistent with the practices of the majority of chiropractors, and consideration of multiple criteria reduces the likelihood of false positive or false negative findings.

Problem Statement

Chiropractors maintain that the presence of vertebral subluxation can lead to negative health outcomes (McCoy M & Kent, 2013). The Association of Chiropractic Colleges defines subluxation as: “a complex of functional and/or structural and/or pathological articular changes that compromise neural integrity and may influence organ system function and general health” (Association of Chiropractic Colleges, n.d.). Yet to date, there have been no large

epidemiological studies that attempted to quantify the prevalence of VS within the general population.

There is therefore a need to estimate the prevalence of vertebral subluxation in the general population, based on the presence of biomechanical and neurological indicators. A high prevalence of subluxation may suggest a potential public health issue, and preventative measures should be aimed at reduction of these indicators. Having this information would be beneficial to the general public as well as the chiropractic profession.

Purpose Statement

The purpose of this paper is to estimate the prevalence of vertebral subluxation (VS) based on neurological and radiographic indicators in patients presenting for chiropractic care from a multi-clinic dataset. Age and gender-stratified prevalence in each clinic will also be calculated. This analysis will provide a basis for primary prevention measures relevant to VS and its implications for health promotion and prevention.

Chapter 2: Review of Literature

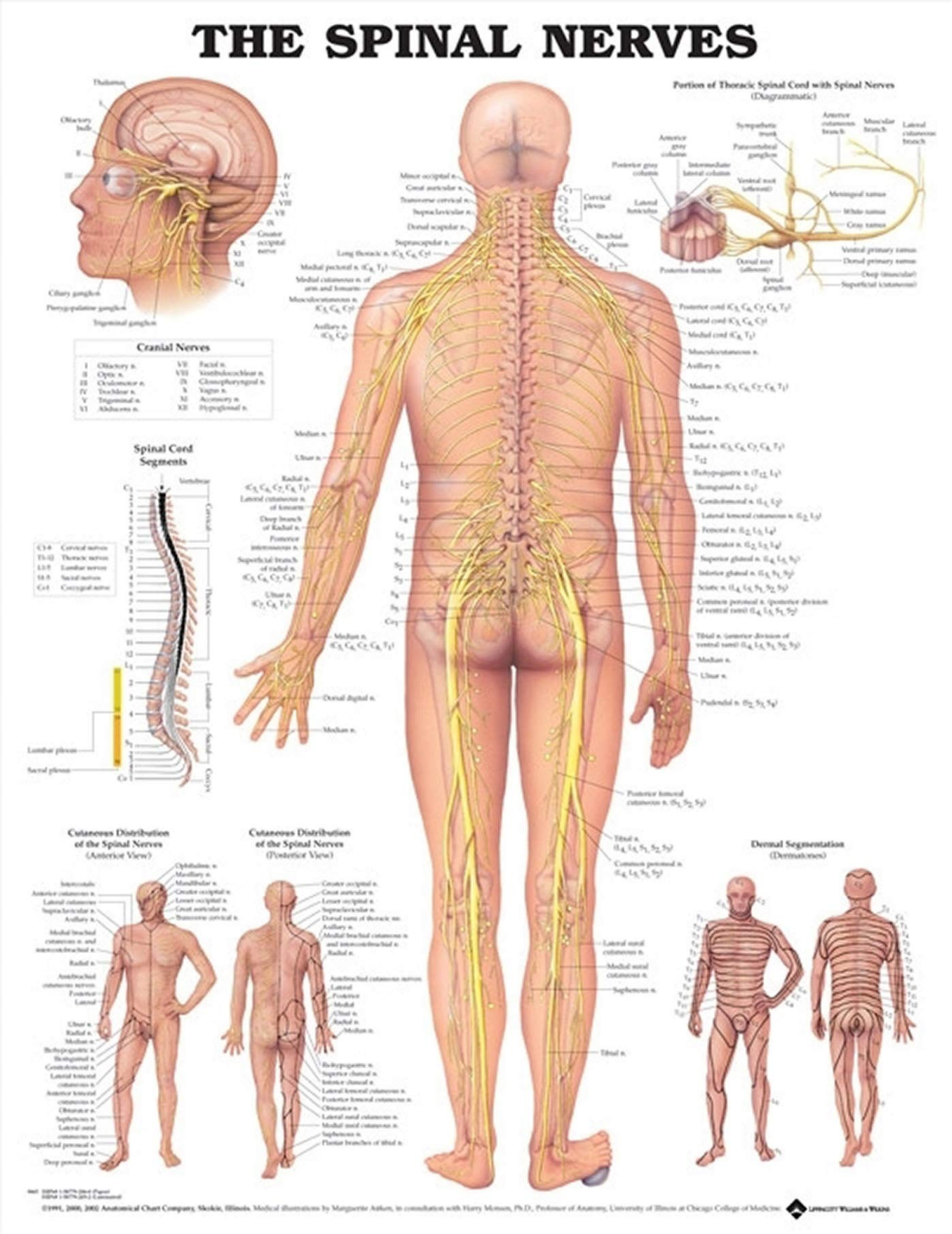
Clinical significance of VS

The primary premise of the chiropractic profession is that the body is a self-maintaining, self-healing organism, and that reducing and/or correcting vertebral subluxations allows the nervous system to function better and allows the fullest expression of life (McCoy M & Kent, 2013). The case history and examination findings together provide evidence for vertebral subluxation at specific spinal levels.

It is important to note that the presence of VS does not require any associated symptomatology to be present; therefore, the evaluation of asymptomatic individuals may result in positive findings as well. Any number of tissues, organs, or body systems can be impacted by misalignment at various levels of the spinal column based on the vast distribution of the peripheral nervous system, and its relationship to other body systems (**Supplemental Figure S1)**. The most commonly reported reasons for people attending chiropractic care have been noted as low back pain (49.7%, IQR: 43.0%-60.2%), neck pain (22.5%, IQR: 16.3%-24.5%), and extremity problems (10.0%, IQR: 4.3%-22.0%) (Beliveau et al., 2017). However, the benefits of VS correction are well beyond analgesic effects and constitute a broad spectrum of salutogenic and health promoting outcomes (Kent, 1996). The literature supports a role for chiropractic is affecting quality of life and overall health. Researchers conducted a survey study of 2,818 adult patients in 156 chiropractic clinics from the United States, Canada, Australia, and Puerto Rico (Blanks, Schuster, & Dobson, 1997). They found that in addition to physiological changes recorded by the chiropractors, patients self-reported significant improvements in four domains of health (physical state, mental/emotional state, stress evaluation, life enjoyment) and quality of life over 1-3 months to 3 years with chiropractic care.

The negative health consequences of VS warrant further exploration (McCoy M & Kent, 2013), but it is important to first estimate the prevalence of VS. Smaller studies have attempted to answer this question and reported subluxation prevalence ranging 90-99.4% in the chiropractic literature ((Bowler, 2019); (Hayden, Mior, & Verhoef, 2003)) and 35-95.1% in orthopedic papers ((Kauppi & Hakala, 1994);(Neva et al., 2006)); conservative management methods are recommended in most of these cases. Medical subluxation was diagnosed based on radiographic measurements alone ((Kauppi & Hakala, 1994);(Neva et al., 2006)). One study's operational definition considered neurologic (leg length inequality and palpation) findings without mention of radiographs (Bowler, 2019). Current prevalence estimates of VS are anecdotal. In this study, a more comprehensive operational definition is attempted to estimate the prevalence of VS in a large sample from a multi-site clinical setting.

Supplemental Figure 1 - The Spinal Nerves



Source: Amazon.com

Methods of evaluation for VS

The purpose of the chiropractic examination is to assess the presence of vertebral subluxation indirectly through measurement of its components. There is no one variable to measure VS; rather, a combination of several variables is used to identify subluxation. Furthermore, there is not a consistent combination of variables agreed upon by all chiropractors; however, there is general agreement on the need to assess neurologic and kinesiologic components. Neurological dysfunction has been traditionally detected through a number of means including static and motion palpation, such as for inflammation and taut-/tenderness, evaluation for leg length inequality, or manual muscle testing. More specific tests including the Fakuda Step Test are used to evaluate the integrity of the cerebellum or dorsal column tracts of the central nervous system. Radiographic evaluation is also used to ascertain the biomechanical component of the VS; imaging allows for the practitioner to measure this misalignment from multiple angles. ”Common to all concepts of subluxation are some form of kinesiolog[ic] dysfunction and some form of neurologic involvement” (Lantz, 1995). Examination findings elucidate the presence and location of vertebral subluxation. However, it is also recognized that VS may have physiological manifestations that are not yet symptomatic.

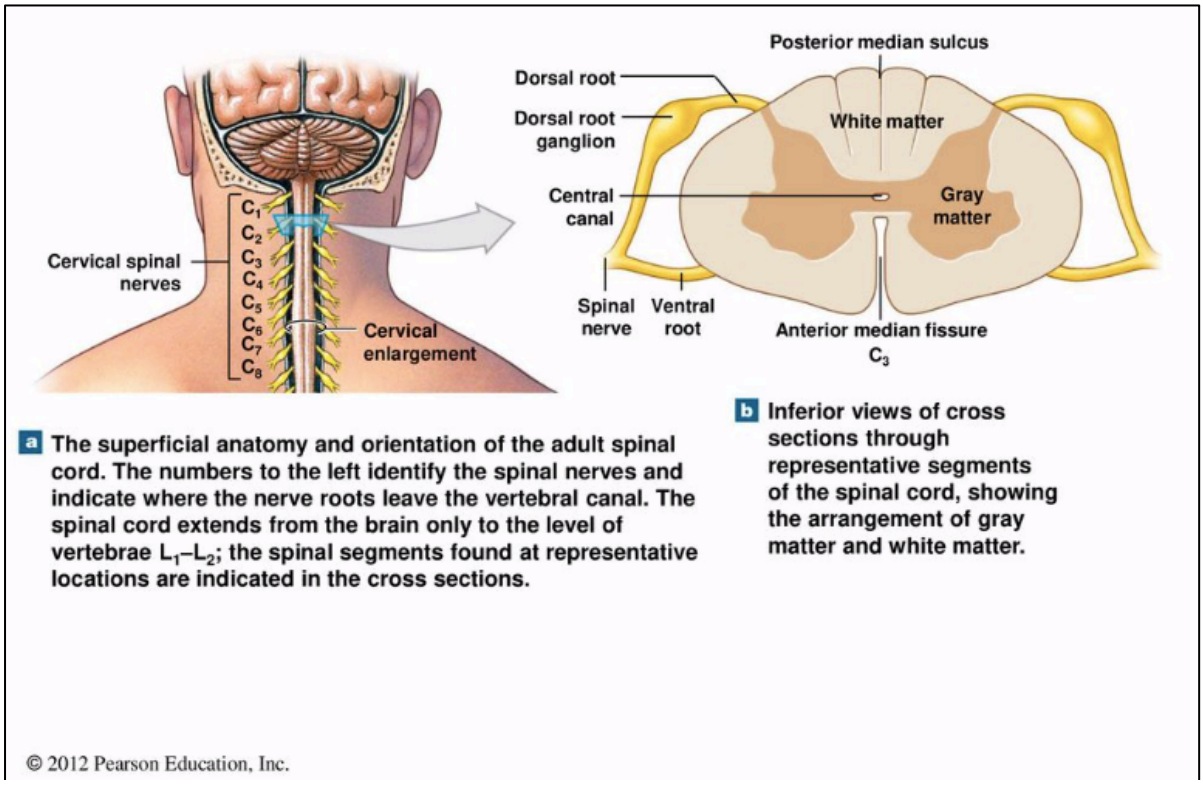
Specific examination components of the operational definition used in this study included (1) inflammation of the C2 (second cervical vertebra) Dorsal Root Ganglion (DRG), (2) leg length inequality, (3) tautness of the erector spinae muscles, (4) upper extremity muscle weakness, (5) Fakuda Step test, and radiographic analysis based on the (6) frontal atlas cranium line) and (7) horizontal atlas cranium line. Each of these direct measurements for VS has been discussed in the published literature heretofore and has shown moderate to high reliability and construct validity (Russell, 2019).

Methods of analysis for neurological dysfunction

Static and motion palpation are used to assess for tenderness, stability, and motion between spinal segments. It assesses the bony anatomy and surrounding soft tissues. Taut and tender fibers, hypermobile segments, hypomobility, or myospasm could all be suggestive of VS. Bony and soft anatomy of the cervical and lumbar spines can be evaluated in this manner.

The cervical spine is palpated to evaluate motion segments and note for any tenderness (**Supplemental Figure S2**). The C2 dorsal root ganglion (DRG), located between the first (C1) and second (C2) cervical vertebrae, is a common sign of nerve entrapment. Due to the small space between C1 and C2, cadaver studies have revealed that this nerve root is highly susceptible to entrapment (Lu & Ebraheim, 1998). Inflammation at this region of the cervical spine can lead to headaches or areas of paresthesia.

Supplemental Figure 2 - Gross Anatomy of the Cervical Spine and Dorsal Root Ganglion



Source: Pearson Education, Inc, 2012.

Neurological disruption at a spinal level can cause reflex misfiring that results in postural distortions such as a functional scoliosis or imbalance of the legs. Leg length inequality is a key component of the chiropractic examination and one of the most commonly used signs of spinal imbalance. Inter- and intra-examiner reliability of leg length assessments has been established by extensive study amongst chiropractors ((Woodfield, Gerstman, Olaisen, & Johnson, 2011); (Holt et al., 2009)).

The erector spinae muscle group is a set of three muscles that run vertically from the base of the skull down the length of the spine and aid in extension of the torso. Tautness and asymmetry of these muscles have been associated with the presence of a functional short leg (Knutson & Owens, 2005), and these two findings collectively support the presence of subluxation.

Manual muscle testing (MMT) has shown good reliability and validity for evaluation of neuromusculoskeletal dysfunction (Cuthbert & Goodheart, 2007). Research suggests that MMT can reveal central or peripheral nervous system issues assessed by both chiropractors and physical therapists. "Manual muscle tests evaluate the ability of the nervous system to adapt the muscle to meet the changing pressure of the examiner's test," according to Cuthbert & Goodheart (2007). Muscle weakness suggests inhibition of anterior horn motor neurons as associated with spinal dysfunction (Cuthbert & Goodheart, 2007). Upper extremity muscle weakness coupled with head rotation is used as an examination procedure in this study.

The Fakuda (aka Unterberger's) step test is a special neurological test used to evaluate for vestibular system-related balance problems. It is commonly associated with vertigo or dizziness. The test measures rotation to the side of lesion while the patient marches in place with eyes closed. The reliability of this exam procedure in determining the side of lesion has been

questioned, particularly in acute cases (Zhang & Wang, 2011), but this procedure is still widely used in clinical practice.

Methods of radiographic analysis of biomechanical dysfunction

Plain-film radiographic imaging is thought to be highly reliable, and imaging is the most objective way to assess the biomechanical component of the vertebral subluxation. There is a high-level of agreement for the use of diagnostic imaging in chiropractic practice (Bussieres, Peterson, & Taylor, 2007). The algorithm of this study focuses on imaging of the cervical spine to determine misalignment based on three-dimensional analysis (Pierce, 2019). Orthogonality of 90 degrees is considered to be the ideal alignment for the cranium in relationship to the cervical spine. The Frontal Atlas Cranium line (FAC) measurement determines the laterality (right or left-sided) component of first (C1) cervical vertebra misalignment along the X-axis plane of the body. The Horizontal Atlas Cranium line (HAC) is a measure of the anterior or posterior misalignment component along the Z-plane with reference to the FAC. Genetic abnormalities and asymmetries can influence these measurements, so cutoff values of >0.25 degrees are commonly considered indicative of subluxation. Measurements are considered to be accurate to $1/100^{th}$ of a degree (EPIC Clinics).

Chapter 3: Methods

Introduction

We utilized a dataset of 3,364 patient records from 12 chiropractic clinics located in 11 different U.S. cities for this retrospective analysis. Data were collected during initial patient exams from March 2009 to October 2019 and recorded in the proprietary SONUS central data repository. Variables of interest included demographic information (date of birth, sex), chief presenting complaints (primary reasons for seeking care, current and chronic symptoms, motor vehicle accident history), spinal radiograph data for biomechanical assessment, and evaluation of five indicators of neurological function. This study attempted to accomplish two aims: (1) estimate the prevalence of vertebral subluxation in patients presenting to a network of chiropractic clinics, and (2) evaluate differences in prevalence by age and gender.

SONUS is the central data repository system utilized by this network of clinics (EPIC Clinics). This proprietary database is used to record de-identified patient history information, examination findings, and follow-up data over the course of chiropractic care. Each variable in SONUS is recorded as 'Right', 'Left, or 'Both' if positive; negative data points were left blank. Initially the data from SONUS had to be imported into SAS. Variables were converted to dichotomous values, '1' (present) and '0' (absent). Because SONUS records negative data as blank values, it was difficult to ascertain whether values were truly negative or missing. Any clinic with series of blanks for any particular neurologic exam variable was considered to have missing data, and the entire clinic was excluded during this process (n=1160, 5 clinics). The data set used in the analysis consisted of samples from clinics in Florida (clinic G), Pennsylvania (clinic B), Texas (clinic F), and Utah (clinics A, C, D, E).

Analysis was limited to clinics that recorded initial exam findings and adult patients (≥18 years of age). Subjects for whom age could not be calculated due to data entry errors were excluded (n=132). Youths (n=221) were not included in the data analysis because it is possible that prevalence is strongly impacted by age, and children's physiology is quite different from that of adults.

In summary, inclusion criteria were:

- clinics that have recorded neurologic exam findings in database
- adult patients (>=18 yo)
- has at least 1 neurologic exam finding (+/-)
- has radiographic finding (+/-)

These were the exclusion criteria:

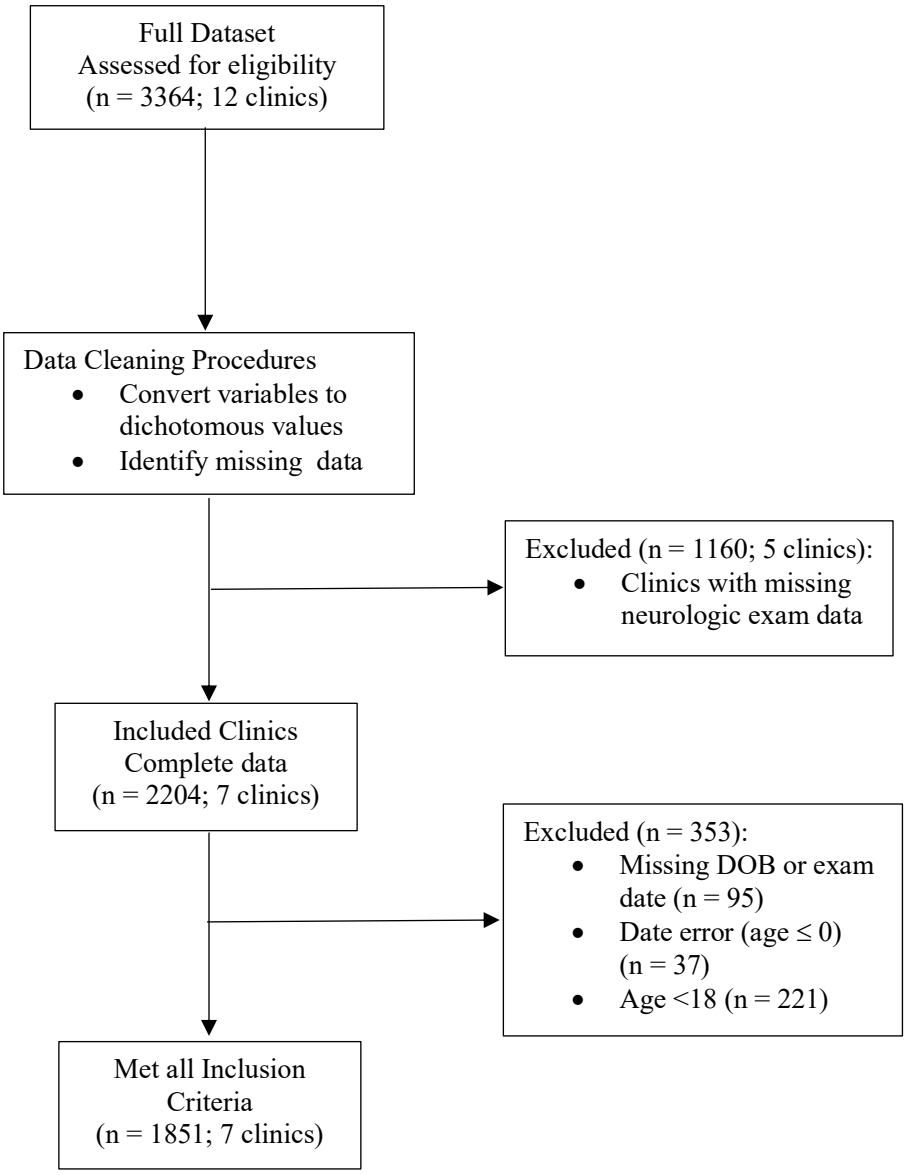
- clinics that did not record their exam findings in database
- children (<18 yo)
- age cannot be calculated due to missing DOB or exam date
- age error (<=0)

After applying the inclusion and exclusion criteria, 1851 subjects from seven clinics were used in this analysis (**Figure 1**); 1513 (45%) patients were removed. Gender was available for 1435 patients from six clinics.

Ethics Statement

Based on the nature of this study, the Emory University Institutional Review Board determined that no further IRB review was required.

Figure 1 - Flow Diagram

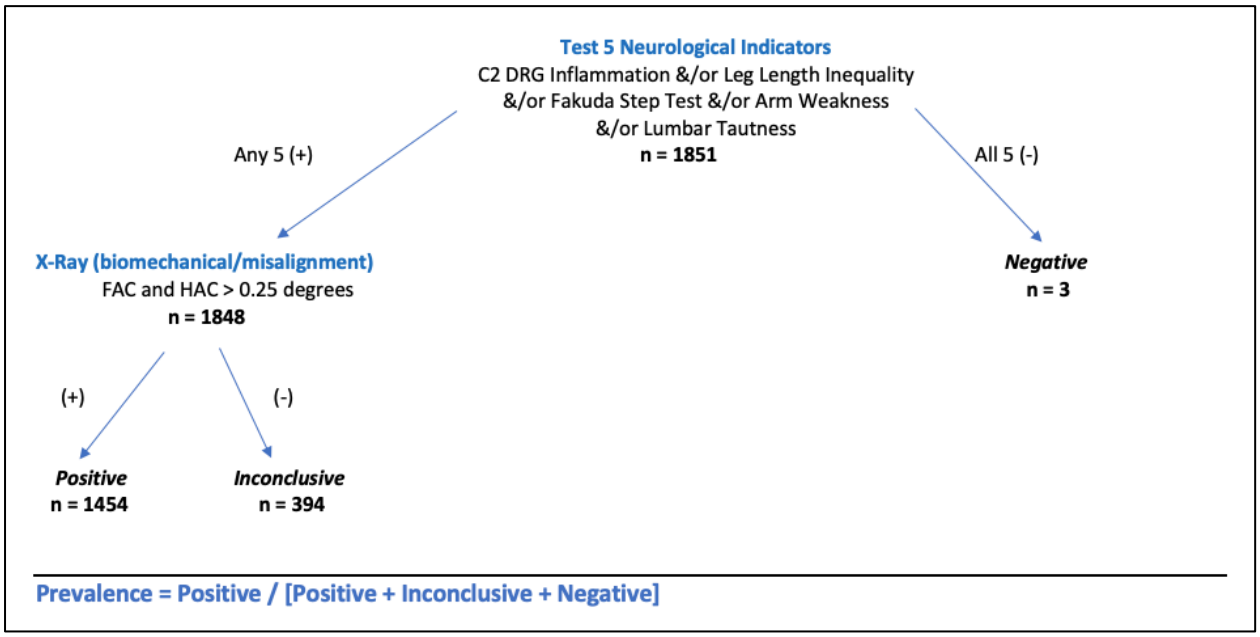


Variables of Interest

Initial examination procedures included analysis based on physical and radiographic findings. Physical exam included testing of five neurological indicators: (1) palpation for inflammation of the C2 DRG [**DRG**]; (2) supine leg length inequality [**SLC**], (3) Fakuda step test [**Fakuda**], (4) right or left arm weakness [**WA**], and (5) lumbar muscle tautness [**LB**]. All physical exam findings were analyzed as dichotomous variables, '1' (present)/'0' (absent). After the data cleaning procedures described above (**Figure 1**), all remaining data were considered complete, and no blanks were further treated as missing data.

Radiographic analysis was used to determine the biomechanical misalignment of the upper cervical spine, based on a combination of two measurements, frontal atlas cranium line (FAC) and horizontal atlas cranium line (HAC) [**FHAC**]. A cutoff measurement value of 0.25 degrees was used for both x-ray mensuration to account for measurement error, anatomical variants, and any other potential anomalies, as per clinic protocol. FHAC was treated as a dichotomous variable as well; any measurements above the cutoff were analyzed as '1' (present) and values below the cutoff were given a '0' (absent) value. **Figure 2** provides a flowchart that shows the algorithm used to determine prevalence; a formula is also included for easy reference. The algorithm reflects the operational definition of vertebral subluxation used in this study.

Figure 2 - Vertebral Subluxation Prevalence Algorithm



Patients were classified as positive (for subluxation) if they met criteria 1) and 2):

1) Presented with a minimum of one neurological indicator of vertebral subluxation
    a. C2 Dorsal Root Ganglion (DRG) tenderness, OR
    b. Positive Fakuda Step test, OR
    c. Leg Length Inequality, OR
    d. Tautness of the erector spinae muscles; OR
    e. Upper extremity muscle weakness;
2) Presented with the biomechanical indicator in conjunction with a neurological finding,
    a. Frontal Atlas Cranium line > .25 degrees, AND
    b. Horizontal Atlas Cranium line >.25 degrees.

Algorithm criteria (Figure 2) required that one neurological indicator (DRG, Fakuda, SLC, LB, or WA) AND misalignment on x-ray must be present to establish the presence of subluxation. Patients who did not meet the first criteria were considered negative, as they did not have any neurological indicators; no further testing was indicated, and no x-ray data were compiled for

these individuals. Patients who were positive for the first criteria but did not meet the second criteria on x-ray were classified as inconclusive. Although they demonstrated signs of potential neurological dysfunction, for this protocol no kinesiologic dysfunction was seen at the spinal level of interest.

In additional to overall analysis of the sample, age-stratified analysis was performed for four groups – (1) 18-30 years (n = 534); (2) 31-50 years (n= 675); (3) 51-70 years (n = 508); (4) > 70 years (n = 134). A gender-stratified analysis was also performed (n = 1435).

Analysis

SAS Enterprise Guide and Microsoft Excel were both used to run the statistical analyses. Patient demographic data were summarized for age, gender, and past health history characteristics of the overall sample as well as per clinic. Prevalence of vertebral subluxation following the algorithm presented in Figure 2 was estimated. Sex-stratified and age-stratified analyses for each of the clinics were also performed.

Chapter 4: Results

Characteristics of the Sample

A total of 1,851 patient records were utilized in this analysis (**Figure 1**). **Table 1** provides a summary of the patient sample demographics. The mean age of patients was 43.48 (SD = 16.8, range: 18-91 years). There were significantly more females (n = 927, 64.6%) than males (n = 508, 35.4%) presented for chiropractic care.

A broad number of presenting symptoms were recorded as the reason for chiropractic care in subjects (n = 642), and many patients reported more than one complaint. Patient reported reasons for presenting to the chiropractor included various forms of spinal or extremity pain, numbness, or tingling; headaches; ear, nose, and throat-related symptoms or conditions; visceral symptoms; mental health concerns; neurocognitive issues; as well as concerns about general health. Two subjects cited overall wellness, and no chief complaint was recorded for 1,209 subjects (65.3%). Twelve total subjects (0.65%) reported history of a motor vehicle accident (MVA).

Analysis by clinic was also performed. The mean age was lowest in clinic C (37.9 years) and highest in clinic G (50.11 years). Clinic C had the largest number of females (64.8%), and clinic F had the smallest (28.7%). No gender information was available for subjects from clinic D.

Table 1 - Patient Demographics and Reason for Chiropractic Care

Clinic	A		B		C		D		E		F		G		Total	
	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%
Sample Size	59		117		125		92		883		129		446		1851	
Age 18 - 30 (n)	14	23.7%	14	12.0%	49	39.2%	21	22.8%	347	39.3%	24	18.6%	65	14.6%	534	28.8%
31 - 50 (n)	18	30.5%	61	52.1%	48	38.4%	44	47.8%	309	35.0%	46	35.7%	149	33.4%	675	36.5%
51 - 70 (n)	22	37.3%	36	30.8%	27	21.6%	19	20.7%	178	20.2%	52	40.3%	174	39.0%	508	27.4%
> 70 (n)	5	8.5%	6	5.1%	1	0.8%	8	8.7%	49	5.5%	7	5.4%	58	13.0%	134	7.2%
Mean Age (SD)	49.37 (17.2)		47.28 (14.7)		37.9 (13.9)		43.45 (16.2)		39.57 (16.3)		46.55 (15.5)		50.11 (16.8)		43.48 (16.8)	
% Female*	36	61.0%	35	29.9%	81	64.8%	--	--	478	54.1%	37	28.7%	260	58.3%	927	64.6%
MVA	0		1		10		1		0		0		0		12	0.65%
Chief Complaints																
Pain [a]	0		65		13		66		2		92		3		241	13.0%
Postural [b]	0		1		0		0		0		7		3		11	0.6%
Neuropathy [c]	2		11		17		1		84		10		3		128	6.9%
HA [d]	0		25		4		30		1		15		3		78	4.2%
Extremity [e]	0		20		9		9		7		9		3		57	3.1%
ENT [f]	5		8		30		4		75		8		3		133	7.2%
NeuroCog [g]	0		1		3		3		19		1		3		30	1.6%
Mental [h]	0		2		44		1		95		1		3		146	7.9%
Visceral [i]	0		4		16		0		48		2		3		73	3.9%
General [j]	0		3		27		0		47		3		3		83	4.5%
Other [k]	1		3		5		2		14		2		3		30	1.6%
Wellness	0		2		0		0		0		0		3		5	0.3%
None	53		30		46		29		593		33		425		1209	65.3%

*n = 1435

[a] Includes neck, mid-, low-back, or sacroiliac pain, possible due to disc involvement

[b] Includes scoliosis, antero- or retro-listhesis

[c] Includes parasthesia, sciatica, cramping, spasm, or foot drop

[d] Includes head pain/pressure or headaches of all types, including migraines

[e] Includes jaw complaints or any extremity or joint pain

[f] Includes all ear, nose, or throat-related complaints including with cranial nerve involvement

[g] Includes neurological (i.e. seizures, tremors, Parkinson disease), cognitive (i.e. dementia, memory loss), or concussion/whiplash/post-concussive issues

[h] Includes anxiety, stress, depression, mood swings, or brain fog

[i] Includes cardiovascular, endocrine, respiratory, gastrointestinal, genitourinary, or reproductive conditions

[j] Includes issues with fatigue, sleep difficulty, weight change, or energy levels

[k] Includes other past diagnoses such as pregnancy, Lyme disease, past history of stroke, or fibromyalgia

Key Findings

Table 2 provides the percent prevalence of positive subjects, along with its 95% confidence interval. Large variations in prevalence are seen between clinics (50-93.88%), and the sample sizes also differ (range 59-883 patients). Prevalence of VS among males (80.15%, n=508)) is similar to that of females (77.17, n=927)%. Prevalence by age demonstrated an inverse relationship with age; the 18-30 group (n=534) demonstrated 86.33% prevalence, while the group of patients over 70 years of age (n=134) had a 73.88% prevalence.

Table 2 - Prevalence of Vertebral Subluxation

	N	Prevalence
Overall (95% CI)	1851	78.55% (76.68,80.42)
Clinic		
A	59	86.44%
B	117	89.74%
C	125	93.60%
D	92	50.00%
E	883	93.88%
F	129	62.79%
G	446	50.45%
Gender		
Female	927	77.17%
Male	508	80.15%
Age Group		
18-30	534	86.33%
31-50	675	76.44%
51-70	508	74.41%
>70	134	73.88%

When age-stratified prevalence was performed in each clinic (**Table 3**), no clear relationship between age group and prevalence was observed. The prevalence of VS for each

clinic and age-stratified group was ≥ 50% except in two 31-50-year-old subgroups from clinics D and G (40.91 and 44.30% prevalence, respectively).

Table 3 - Prevalence of Vertebral Subluxation, per clinic and age-stratified

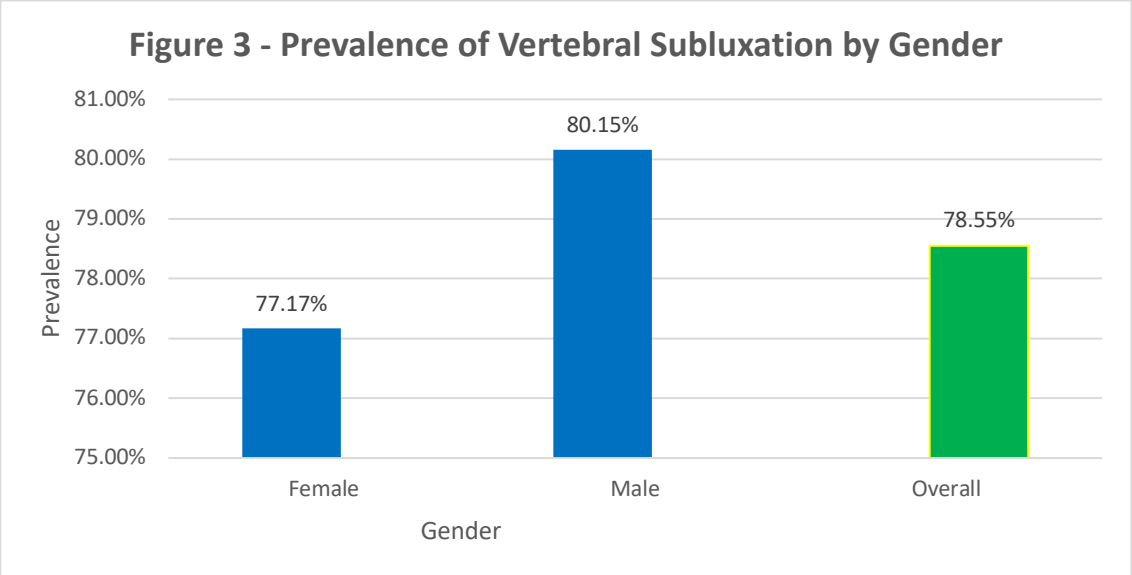
	Age-Stratified Prevalence *positive/total (% prevalence)*				
Clinic	**18-30**	**31-50**	**51-70**	**>70**	**Overall**
A (n=59)	12/14 (85.71%)	17/18 (94.44%)	17/22 (77.27%)	5/5 (100.00%)	51/59 (86.44%)
B (n=117)	12/14 (85.71%)	56/61 (91.80%)	31/36 (86.11%)	6/6 (100.00%)	105/117 (89.74%)
C (n=125)	48/49 (97.96%)	45/48 (93.75%)	23/27 (85.19%)	1/1 (100.00%)	117/125 (93.60%)
D (n=92)	12/21 (57.14%)	18/44 (40.91%)	11/19 (57.89%)	5/8 (62.50%)	46/92 (50.00%)
E (n=883)	324/347 (93.37%)	288/309 (93.20%)	170/178 (95.51%)	47/49 (95.92%)	829/883 (93.88%)
F (n=129)	14/24 (58.33%)	26/46 (56.52%)	35/52 (67.31%)	6/7 (85.71%)	81/129 (62.79%)
G (n=446)	39/65 (60.00%)	66/149 (44.30%)	91/174 (52.30%)	29/58 (50.00%)	225/446 (50.45%)
All Clinics (n=1851)	461/534 (86.33%)	516/675 (76.44%)	378/508 (74.41%)	99/134 (73.88%)	1454/1851 (78.55%)

Summary Findings

The overall prevalence of radiographic and neurological findings indicating presence of vertebral subluxation was found to be 78.55% (95% CI: 76.68%-80.42%). Interestingly, prevalence of VS was higher in younger groups (ages 18-30 = 86.33%) and was decreasing with age (> 70 years = 73.88%) in the overall sample. There was greater age-stratified variation at the per-clinic level; however, a high prevalence of VS is seen in all older age groups. Per clinic, >95% prevalence was seen in 4 of 7 clinics for the >70 group, 1 of 7 clinics for ages 51-70, 0 of 7 clinics for ages 31-50, and 1 of 7 clinics for ages 18-30 (**Table 3)**. When the data are viewed this way, a possible increasing prevalence in older age groups emerges.

Prevalence of VS for females (77.17%, 95% CI: 78.33%-81.97%) was similar to that of males (80.15%, 95% CI: 75.25$-79.08%). (**Figure 3**).

Figure 3 - Prevalence of Vertebral Subluxation by Gender



Chapter 5: Conclusions, Implications, and Recommendations

Study Summary

A multi-clinic dataset of 3,364 patients presenting for chiropractic care was to estimate the prevalence of vertebral subluxation. After data cleaning procedures, data from 1,851 subjects were available for overall, age-stratified, and gender-stratified analysis. The prevalence of VS was calculated using an algorithm that requires two criteria - the presence of at least one neurologic indicator ([**DRG**], [**SLC**], [**Fakuda**], [**WA**], or [**LB**]) and a minimum cutoff value for the radiographic findings [**FHAC]**.

Discussion

The overall prevalence of vertebral subluxation using data from six clinics was 78.55% (95% CI: 76.68%-80.42%). Notably, ≥ 50% prevalence was found for each individual clinic, although variations were observed between clinics. Prevalence by gender was 77.17% for females (715 of 927) and 80.15% for males (407of 508). The data in this study are consistent with previously published work in that women are more likely to visit a chiropractor (Beliveau et al., 2017). However, the high prevalence of VS found in this study suggests that it may be of equal importance that men also seek chiropractic evaluation. There are both environmental and biological factors that influence gender prevalence in health (Regitz-Zagrosek, 2012). However, in the sequelae of disease processes, each of these factors possibly aggravates the progression of a disease. The VS is not a disease entity but rather a condition of reduced functional efficiency of the nervous system (McCoy M & Kent, 2013); the presence of VS could lay the foreground for declining health.

A broad number of chief complaints were cited by patients as their reasons for seeking chiropractic care. These included various forms of spinal or extremity pain, numbness, or tingling; headaches; ear, nose, and throat-related symptoms or conditions; visceral symptoms; mental health concerns; neurocognitive issues; as well as concerns about general health. Two subjects cited overall wellness, and no chief complaint was recorded for 1,209 subjects (65.3%). Twelve total subjects (0.65%) reported history of a motor vehicle accident (MVA). Follow-up analysis on the resolution of patient-reported symptomatology along with a reduction in subluxation indicators from chiropractic care may help elucidate the impact of VS on health promotion and prevention.

Furthermore, prevalence by age was found to decrease with increasing age in the overall sample. However, this seemingly inverse relationship between age and prevalence of subluxation did not persist within individual clinics and may thus constitute an incidental finding. It is commonly known that there is an exponential rise in mortality rates with ageing (Ferrucci, Giallauria, & Guralnik, 2008). Notably, in six of the seven clinics, the highest prevalence was still seen in the oldest age category (n=134). 95% or higher prevalence was seen at the highest frequency in this group - in 4 of 7 clinics for >70 years of age, 1 of 7 clinics for ages 51-70, 0 of 7 clinics for ages 31-50, and 1 of 7 clinics for ages 18-30. It is possible that older populations with subclinical symptomatology are presenting to a chiropractor. The literature shows that health promoting activities reduce morbidity at older ages even without an impact on population life expectancy (Ferrucci et al., 2008). The implication of these findings is that quantifying the prevalence of subluxation may play a key role in longevity and quality of life through health promotion and disease prevention. The WHO defines health as “a state of complete physical, mental and social well-being and not merely the absence of disease or

infirmity" (World Health Organization, 2020). Chiropractic care is associated with improvement in multiple health domains, including physical state, mental/emotional state, stress evaluation, and life enjoyment (Blanks et al., 1997). Chiropractic management of VS at younger ages may prevent further health challenges at later stages in life. As seen with this analysis, older individuals exhibit greater prevalence of unmanaged VS, and as seen in the published literature, older populations generally experience greater morbidity. Furthermore, quality of life is improved through chiropractic care alongside health promotion (Blanks et al., 1997).

A subset of the sample (n = 394) was classified as inconclusive, alongside positive (n = 1454) and negative (n = 3) individuals. This subgroup is significant in its role on the numerator and denominator used to calculate prevalence. The inconclusive group is defined as subjects who have at least one neurological indicator but do not meet the criteria set forth for the biomechanical component of the operational definition for VS (Figure 2). However, the radiographic analysis was limited to two criteria, FAC and HAC, with a cutoff value of >0.25 degrees to account for genetic anomalies in the individual cervical spines. Incorporating additional radiographic criteria or lines of mensuration in the operational definition could significantly increase the prevalence calculations presented in this study.

As outlined in Figure 1, data from 5 clinics (n = 1160) were excluded from this analysis due to missing neurological exam data. This relatively large subset of the data potentially affects prevalence estimates. Some of these groups of patients had radiographic exam data recorded in SONUS. Thus, it may be presumed that they met neurological criteria according to the VS algorithm presented in Figure 2. However, that exam information was not uploaded to SONUS by specific clinics. Inclusion on the basis of the radiographic criteria alone may have increased prevalence estimates reported on the entire dataset.

Overall, it is important to note a high prevalence of VS in all subgroups as well as the total sample based on the operational definition adopted in this study. Although there was variability of findings between clinics, all clinics showed agreement that over half of the subjects examined were positive for VS (50.45-93.88%). Four of seven clinics' data revealed >95% prevalence in the oldest age group. All but two age & clinic-stratified subgroups reported ≥ 50%, further suggesting the high prevalence of VS in the general population.

Strengths and Limitations

This is the first ever study to date that has attempted to estimate prevalence of vertebral subluxation using a large sample from a multi-clinic dataset. Prevalence estimates are highly dependent on the adopted operational definition, which must be concrete, evidence-based, and comprehensive. An operational definition should include valid measurements and processes that reduce the likelihood of false positives and false negatives. In this case, an operational definition that incorporated a number of direct measures of neurologic and kinesiologic subluxation components commonly used in chiropractic clinical practice was used as the basis for analysis. Previous studies reported anecdotal prevalence estimates based only on neurological findings or biomechanical measures in small samples.

Although the size and broad geographic distribution across seven clinics, six cities and four states are strengths of the study, the dataset was derived from a population that has already presented for chiropractic care. This suggests possible selection bias; that is, subjects may not be representative of the general population. They may have been symptomatic or had some other driving reason to be analyzed for VS in the first place.

Missing data was an additional limitation in this dataset. When fields were left blank, this omission was deemed intentional and meant to indicate a null value. However, if a particular field was blank for the majority of patients from a specific clinic, it was assumed to be missing data rather than negative findings; these clinics were excluded from analysis. As discussed previously, it is likely that missing data affected the prevalence estimates. Errors in age (≤ 0 years) were also excluded from the analysis.

The calculation for confidence interval of the overall sample prevalence assumed each patient as independent. However, clinic-stratified analysis revealed a clinic effect – findings for each clinic and its clustered sample are different. A clustering effect is possible and may warrant consideration confidence interval calculations for the overall prevalence estimate.

It would be presumed that little geographic variation of subluxation prevalence would occur, but there were significant variations per clinic in this dataset. This could have been due to data entry issues but was likely influenced by variance in the sample size from each clinic. Data from clinics with larger sample sizes can dominate the analysis and create statistical artifacts at the macroscopic level that vary from what is seen when examining the same data by individual clinics. Although there was a high level of variability in prevalence between clinics, all clinics showed agreement that over half of the subjects examined were positive for VS (50.45-93.88%). Gender data was unavailable from one clinic.

Finally, 1208 of the subjects have no chief complaint of record. Since ‘wellness’ is a possible option for visiting the chiropractor, we could not assume that a blank field corresponded to an asymptomatic patient. Therefore, representative estimates of prevalence based on chief complaint could not be calculated from Table 1.

Conclusions

The results of this study suggest a high rate of prevalence of vertebral subluxation in a study population. Despite inherent limitations of this limited sample, the broad geographic distribution of the clinics suggests these findings hold some generalizability and may be representative of the general population. This is the first study of its magnitude and application of an operational definition to estimate prevalence of VS. Further investigation into the epidemiology of vertebral subluxation is warranted in order to strengthen inferences about the role of subluxation in health and longevity. More robust data collection in multiple clinics using the same assessment tools is recommended to expand this knowledgebase. There may be a need to evaluate and expand the operational definition of VS based on reliable and valid criteria. Consideration should be given to whether additional radiographic analysis is warranted in the inconclusive group that presents with neurological findings but does not meet the criteria for misalignment by the operational definition adopted in this study. Future studies should examine longitudinal outcomes of care in order to further elucidate the public health implications of the prevalence of vertebral subluxation.

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