Technical Report

Changes in clinical and radiographic parameters after a regimen of chiropractic manipulation combined with soft tissue therapy and neuromuscular rehabilitation in 7 patients with Adolescent Idiopathic Scoliosis

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Abstract

Background

The causes of idiopathic scoliosis (IS) are likely multifactorial, including genetic and environmental. It is unlikely one therapy addresses all involved factors. Evidence supports a comprehensive approach to evaluation & treatment using a variety of outcome assessments.

Aim

This study presents a review of files of seven adolescent idiopathic scoliosis (AIS) patients treated with a comprehensive two-week treatment protocol including chiropractic manipulative therapy, massage, exercise, and whole-body vibration therapy, followed by a home rehabilitation regimen.

Method

Primary outcome measures reported include Cobb angle, apical vertebral rotation, disc index, apical vertebral deviation, digital spirometry, scoliometry, timed one-legged stability with eyes closed (TOLSWEC), and computerized dual inclinometry, as well as pain drawings and health-related quality of life questionnaires (RAND SF-36 and SRS-22). Data was recorded post-treatment and at follow-up ranging from four to seven months. A Wilcoxon test was performed to assess the statistical significance of the pre and post treatment outcome parameters. Each patient underwent twenty treatment sessions over a two week period (2x day/five days) for an average length of 180 minutes/session. Treatment sessions were divided into three phases. The first phase of treatment addressed soft tissue deformations and improving spinal flexibility, the second phase influenced spinal biomechanics, and the third impacted neuromuscular function.

Results

The mean and range for the following primary outcome measures were recorded post-treatment: Cobb angle changes: thoracic (8.4^o, 6.5^o – 11^o); lumbar (8^o, 0^o - 12^o); apical vertebral rotation: thoracic (5.9%, 1.8% – 19.6%); lumbar (5.4%, 0% – 13.5%); disc index: thoracic (0.18, 0.01 – 0.4); lumbar (0.06, -0.2 – 0.44); apical vertebral deviation: thoracic (-2.3 mm, -21.5 mm to 13 mm); lumbar (5.6 mm, 4 mm – 7 mm); forced vital capacity: (237 cc, 0-820 cc); forced expiratory volume in 1 second: (212 cc, -50 cc to 520 cc); forced expiratory rate: (5%, -2% to 18%); peak expiratory flow: (420 cc, -960 cc to 1180 cc); scoliometer readings: (3.0^o, -1^o to 10^o); TOLSWEC: left (3 seconds, -8 to 13); right (6 seconds, -3 to 24); pain scales (-1.4, +1 to -4); RAND SF-36: (8%, -21% to 36%). The greatest mean improvements in spinal ranges of motion (ROM) occurred in thoracic rotation, lumbar flexion, and lumbar lateral flexion.

At follow-up, Cobb angle progression was prevented in **two** patients and reversed in **two**; two patients progressed past pre-treatment levels. Mean SRS score was 3.91.

Conclusion

The applied protocols effected positive functional and/or radiological changes in seven cases of AIS, with two cases demonstrating continued benefit at follow-up.

Background

Scoliosis is a three-dimensional spinal deformity characterized by lateral deviation.[1] Most cases are classified as having no directly attributable cause (idiopathic),[2] and categorized by the time of detection.[3] However, the causes of idiopathic scoliosis (IS) are likely multifactorial, including genetic and environmental.[4-7]

Adolescent idiopathic scoliosis (AIS) is the leading orthopedic problem in school age children.[8] Traditional management of AIS consists of observation from 10^o to 30^o, bracing from 30^o to 40^o, and surgery at over 40^o.[9-11] The goal of bracing is to prevent progression; yet there is very low quality evidence that braces are more effective than observation in curbing the increases in the curves of the spine.[12-14] The goals of surgery are to prevent progression, and diminish spinal deformity; however, a superior outcome to natural history and medical necessity have not been established for this procedure.[15-18]

Alternative AIS treatment methods include exercises, manual therapy, and electrical stimulation. The evidence is favorable for exercise[19] while the evidence behind the efficacy of manual therapy is inconclusive.[20] Evidence indicates electrical stimulation is not effective for curbing curve progression.[21]

It is unlikely one therapy addresses all involved factors. Evidence supports a comprehensive approach to evaluation & treatment using a variety of outcome assessments.[22-24] Combining spinal manipulation with postural therapy has been reported to reduce the severity of scoliosis in 19 individuals,[25] and additional studies have documented the benefit of manual therapy combined with other therapies.[26-32] This manuscript presents a review of files of seven adolescents with AIS treated with a combined approach of chiropractic manipulation therapy

(CMT), massage, neuromuscular re-education, whole-body vibration (WBV) therapy, and exercise therapy.

Methods (Case presentation)

Patient population

The authors conducted a retrospective review of seven consecutive case files of patients with AIS who presented for treatment between 1-1-2011 to 9-1-2011 at a private practice in Dallas, Texas. All patients were between 9 to 17 years of age with a Risser sign of less than 4, and followed a two week treatment protocol. All patients were negative for malignancy, fractures, arthrodesis, and neurological or congenital defects (including anatomical leg length inequality).

Written informed consent to treatment, radiographic procedures, and the use of data for research purposes was obtained from each patient's parent or legal guardian. File numbers were changed to protect the identities of each patient. There were 2 males and 5 females, average age 15 years (range 10 to 17). Six patients presented with double thoracic & lumbar ("S") curves; one with a single thoracolumbar ("C") curve. The Cobb angles averaged 51.6 (range 36.5 - 65) thoracic and 41.9 (range 23 - 53) lumbar. Two of the five females were pre-menarchal. Family history for scoliosis was positive in two individuals. Three patients presented with absent superficial abdominal reflexes (SAR) but no other abnormal neurological findings. See Table 1.1.

Table 1.1 – Patient Descriptors

ID	Gender	Age	Curve	T Cobb	T Vert	L Cobb	L Vert	Menarche	Fam H	Risser	SAR
1	M	12	C	59	T9-L3, T12	n/a	n/a	n/a	-	0	-
2	F	12	S	45	T7-T12, T9	45	T12-L4, L2	3/08	+	1	-
3	F	15	S	58.5	T5-T11, T9	51	T12-L4, L2	11/10	-	4	+
4	F	13	S	63	T4-T10, T8	53	T11-L4, L2	7/11	-	1	-
5	M	14	S	55.5	T6-T10, T8	48	T11-L4, L2	n/a	-	3	+
6	F	15	S	44	T5-T11, T8	31.5	T11-L4, L2	pre	+	1	+
7	F	10	S	36.5	T6-L1, T8	23	L1-L4, L2	pre	-	0	+

ID = patient identification number; T Cobb – thoracic Cobb angle; T Vert – terminal and apical vertebrae for thoracic curve; L Cobb – lumbar Cobb angle; L Vert – terminal and apical vertebrae for lumbar curve; Fam H – family history of scoliosis; SAR – superficial abdominal reflex

Clinical and radiological outcomes

Standards of care and physical examinations were performed on all patients. Primary clinical outcome measures included digital spirometry;[33,34] scoliometry[35] in Adam's position at T6, T12, and L3; timed one-legged stability with eyes closed (TOLSWEC);[36] and, computerized dual inclinometry (Myo-Logic MSM7000™).

Primary radiographic measurements were Cobb angle, vertebral rotation, disc index,[37] and apical lateral deviation. Apical vertebral rotation was assessed as described by Nash and Moe[38] and used by Weinstein and Ponseti,[37] by measuring the distance between the lateral edge of the vertebral margin and the convex pedicle and expressing the rotation as a percentage of the vertebral body width. Disc index was measured as described by Korovessis *et al*,[39] by dividing the disc height on the convex side by the disc height on the concave side. Deviation from the intercrestal line was measured as described by Wu *et al*,[40] drawing a vertical line from L5, and measuring the distance from the center of the apical vertebra to this line.

Questionnaires included Visual Analogue Scale (VAS) using a pain drawing at pre- & post-treatment, the RAND SF-36 pre-treatment, and the RAND SF-36 and SRS-22[41] at follow-up.

Secondary outcome measures included grid photography from the front, side, and back, both standing and in Adam's position; orthopedic and neurological tests, including SAR; and computerized manual muscle testing (Myo-Logic MSM7000™).

Procedure

Radiographs were taken to obtain the cervicodorsal, thoracic, and/or lumbar Cobb angle, and the coronal, sagittal and kinematic relationship between each adjacent vertebral section. Focal film distance, center ray position, patient position, and cassette size were clearly specified (see Table 1.2). Measurements were used to quantify the degree of abnormal sagittal spinal curvature as well as the coronal & axial deviations. Information was used to determine the specific manual & instrument-assisted manipulative therapies, the spinal weighting protocols, and physical therapies. The structural nature of each patient’s spine was confirmed through the use of low-dosage (0.91 rad/min) video fluoroscopy (Digital Motion X-Ray™, DMX Works). In each case, the curvature did not disappear during lateral flexion.

Table 1.2 – Radiographic Protocols

	Focal Film Distance	Center Ray	Patient Position	Cassette Size
Lateral Cervical Neutral	60”	C1	Seated, with hips, knees, & ankles at 90°.	10” x 12”
Lateral Cervical Flexion/Extension	60”	C1	As LCN. Go into full flexion/extension 3 times; drop chin then flex with no active muscle contraction for flexion; raise chin then extend with no active muscle contraction for extension.	10” x 12”
Base Posterior	42”	Through C1 & External Auditory Meatus	Seated with hips, knees & ankles at 90°. Head in full extension, headclamps on ears.	10” x 12”
Nasium (APOM)	42”	C1	Seated with hips, knees, & ankles at 90°. Headclamps placed on ears.	7” x 17”
Lateral Lumbar	42”	L5, 2” below iliac crest	Seated as above with arms crossed & hands on shoulders.	7” x 17”
A-P Lumbar	42”	L5, 2” below iliac crest	Seated as above with arms crossed & hands on shoulders.	14” x 17”
Standing Scoliosis	72”	Centered to apex of curvature	Barefoot, standing erect in a relaxed posture.	Two 14” x 17” (to minimize distortion)

LCN – lateral cervical neutral radiograph; APOM – anterior to posterior open-mouth radiograph

Each patient underwent twenty treatment sessions over a two week period (2 times daily/ten days) for an average length of 180 minutes/session.

Treatment sessions were divided into three phases. The first phase has six parts: active spinal mobility exercises, passive vibration therapy, active cervical traction exercises, massage therapy, passive flexion-distraction therapy, and mobilization therapy (see figures 1-6).

The second phase consisted of CMT. Supine thoracic, prone lumbar, side-posture pelvic manual manipulations, and, seated cervical instrument-assisted manipulations (ArthroStim™ – Impac, Inc.) were performed (see figures 7-10).

The third phase consisted of three parts: reactive body weighting therapy, isometric spinal exercises, and vibration therapy (see figures 11-13).

Each patient was instructed to perform at-home exercises and therapies designed to correlate with their particular case for 30 - 60 minutes, 2/day. Each patient was provided with equipment; included were a cervical traction device, foam rolls and wedges, an air-filled balance training disc, weighted headbands and belts, and a weighted cantilever. Patients were instructed to obtain a Scoliosis Traction Chair (Vibe For Health™) for use at home twice daily for 30 minutes.

Follow-up was conducted at an average of five months (range 4 to 7), and included an at-home exercise performance log to be filled out by the parent/guardian, RAND SF-36 and SRS-22 to be filled out by the patient, and a standard scoliosis x-ray taken at an appropriate location and sent to the primary author for analysis. A Wilcoxon test was performed to assess the statistical significance of the pre and post treatment outcome parameters.

Results

The mean and range for the following primary outcome measures were recorded: Cobb angle changes: thoracic (8.4^o, 6.5^o – 11^o); lumbar (8^o, 0^o - 12^o); apical vertebral rotation: thoracic (5.9%, 1.8% – 19.6%); lumbar (5.4%, 0% – 13.5%); disc index: thoracic (0.18, 0.01 – 0.4); lumbar (0.06, -0.2 – 0.44); apical vertebral deviation: thoracic (-2.3 mm, -21.5 mm to 13 mm); lumbar (5.6 mm, 4 mm – 7 mm); forced vital capacity: (+237 cc, 0-820 cc); forced expiratory volume in 1 second: (+212 cc, -50 cc to 520 cc); forced expiratory rate: (5%, -2% to 18%); peak expiratory flow: (420 cc, -960 cc to 1180 cc) scoliometer readings: (+3.0^o, -1^o to 10^o); TOLSWEC: left (3 seconds, -8 to 13); right (6 seconds, -3 to 24). The greatest mean improvements in spinal ranges of motion (ROM) occurred in thoracic rotation, lumbar flexion, and lumbar lateral flexion (see Tables 2.1 – 2.3).

In the three patients who presented with significant pain, VAS pain scales demonstrated improvement (from 6, 6, 5 to 3, 2, 2, respectively). One patient with very mild initial pain reported a slight increase post-treatment (from 1 to 2) (see Table 2.4).

Re-emergence of the SAR was noted in the three patients with previously absent SAR. The greatest improvement in muscle strength occurred in the hip flexors (see Table 2.5).

At follow-up, the Cobb angles in **two** patients demonstrated continued improvement, **two** regressed but not to pre-treatment levels, and **two** patients regressed past pre-treatment levels (see Table 2.6 for additional radiographic outcomes). The mean and range for changes in RAND SF-36 scores was 8% (-21% to 36%). The mean and range for the SRS-22 score post treatment was 3.91 (3.64 to 4.45).

The results of the Wilcoxon test demonstrated…

Table 2.1 –Pre & Post Spirometry, Scoliometry, & One-Legged Stability

ID	FVC (cc)	% PV FVC	FEV1 (cc)	% PV FEV1	FER (%)	PEF (cc)	Scol T6	Scol T12	Scol L3	OLS L (sec)	OLS R (sec)
1	3220/3380	71/75	2220	56/68	68/79	1400/2570	4/1	13/9	5/4	3/10	6/30
2	2360/2440	59/61	2000	57/60	87/86	1370/2550	15/14	5/2	13/5	12/4	7/4
3	3100/3190	66/69	2680	69/69	87/85	3780/4020	23/25	15/15	5/0	30/30	30/30
4	1820/1820	54/54	1490	48/46	81/99	1120/1300	7/9	14/4	10/2	30/30	30/30
5	3270/4090	58/73	3150	67/78	96/97	5960/5000	12/14	9/2	12/3	30/30	30/30
6	2190/2370	51/55	2090	56/56	89/93	2620/2710	9/9	6/2	0/0	4/17	4/9
7	1490/1820	41/51	1380	41/55	96/97	1750/2770	10/10	2/1	4/1	4/4	8/6
MN	237	5	213	5.4	5	420	1.1	3.4	4.4	3	6

FVC – forced vital capacity; %PV FVC - percent predicted values (age/height/gender) for forced vital capacity; FEV1 – forced expiratory volume in one second; %PV FEV1 – percent predicted values (age/height/gender) for forced expiratory volume in one second; FER – forced expiratory rate; PEF – peak expiratory flow; Scol T6 – scoliometer reading at T6, T12, & L3 respectively, measured in degrees; OLS L/R – timed one-legged stability with eyes closed on left & right foot respectively, measured in seconds; MN – mean.

Table 2.2 – Pre & Post Spinal Ranges of Motion

ID	C Ext	C Flex	C LF L	C LF R	C Rot L	C Rot R	T Ext	T Flex	T Rot L	T Rot R	L Ext	L Flex	L LF L	L LF R
1	72/73	71/66	55/49	21/35	94/80	86/73	17/32	8/26	24/41	30/55	50/39	60/47	38/39	28/23
2	57/58	55/63	53/45	35/31	37/66	40/59	30/22	19/38	21/35	27/44	11/7	41/78	14/55	23/39
3	55/95	64/67	58/64	43/35	80/95	77/87	18/38	21/33	14/19	14/17	15/19	30/71	42/DNC	31/DNC
4	DNC	DNC	DNC	DNC	DNC	DNC	DNC	DNC	DNC	DNC	DNC	DNC	DNC	DNC
5	DNC	DNC	DNC	DNC	DNC	DNC	DNC	DNC	DNC	DNC	DNC	DNC	DNC	DNC
6	DNC	DNC	DNC	DNC	DNC	DNC	DNC	DNC	DNC	DNC	DNC	DNC	DNC	DNC
7	51/51	49/45	56/46	37/46	86/91	80/77	5/10	16/6	17/DNC	24/DNC	5/DNC	14/DNC	19/DNC	21/DNC
MN	10.5	0.5	-4.5	2.8	8.8	3.3	8	9.8	12.7	14.9	1.4	29.1	18.8	5.3

All measurements are in degrees. C Ext – cervical extension; C Flex – cervical flexion; C LF L/R – left/right cervical lateral flexion; C Rot L/R – left/right cervical rotation; T Ext – thoracic extension; T Flex – thoracic flexion; T Rot L/R – left/right thoracic rotation; L Ext – lumbar extension; L Flex – lumbar flexion; L LF L/R – left/right lumbar lateral flexion; DNC – data not collected (due to failure of the equipment to function properly on scheduled exam days); MN – mean.

Table 2.3 – Primary Radiographic Outcomes

ID	T Cobb (deg)	T Rot. (%)	T Disc Ind	T Dev. (mm)	L Cobb (deg)	L Rot. (%)	L Disc Ind	L Dev. (mm)
1	59/49	27.5/23.8	1.9/1.5	53/40	n/a	n/a	n/a	n/a
2	45/38	12.5/7	1.6/1.5	7/16	45/36	24.3/10.8	1.4/1.36	32/26
3	58.5/51	26.5/24	1.7/1.3	33.5/26	51/39	6.5/4.3	1.57/1.77	35/28
4	63/52	19.6/0	1.54/1.53	24/18	53/45	12/0	1.53/1.15	35/30
5	55.5/49	21.4/19	2.03/1.96	32.5/54	48/48	17.4/15.2	1.5/1.7	39/29
6	44/35.5	12.5/10.7	1.38/1.16	22/31	31.5/21	10.5/7.9	1.24/1.35	19/15
7	36.5/26.5	16.1/10.7	1.15/1.08	23/26	23/14.5	0/0	1.6/1.16	11/6.5
MEAN	51.6/43	19.4/13.6	1.6/1.4	27.9/30.1	41.9/33.9	11.7/6.4	1.5/1.4	28.5/22.4

T/L Rot – thoracic/lumbar vertebral rotation; T/L Disc Ind – thoracic/lumbar disc index; T/L Dev – thoracic/lumbar apical vertebral deviation; n/a – not applicable

Table 2.4 – Questionnaires

ID	Pre VAS	Post VAS	Pre RAND (%)	Follow-up RAND (%)	Follow-up SRS-22
1	2	1	52	88	3.84
2	6	3	67	74	4.02
3	6	2	73	86	4.45
4	0	0	68	72	3.68
5	0	0	96	75	3.64
6	1	2	52	56	3.66
7	5	2	75	87	4.08
MEAN	2.9	1.4	69	77	3.96

Table 2.5 – Muscle Strength Testing

ID	Cervical Flex	Cervical Ext	C L Lat Flex	C R Lat Flex	L Hip Flex	R Hip Flex
1	5.7/6.1	5/7.4	3.6/4.3	3/5.2	7.9/15.4	7.7/17
2	3.3/2	4.7/2.7	2.9/2.4	2.9/2.3	5/8	7.1/11.3
3	2/4.1	4.5/2.3	2.7/2.5	2.4/3.3	10/13.7	12.6/12.9
4	DNC	DNC	DNC	DNC	DNC	DNC
5	3/4.2	5.7/5.8	5.7/4.8	6.9/6.6	12.1/22.1	18/23.8
6	DNC	DNC	DNC	DNC	DNC	DNC
7	2/2.1	2.2/2.4	2.5/2.1	2/2.1	3.4/4.7	3.7/6.8
MEAN	0.5	-0.3	-0.26	0.46	5.1	4.54

All measurements expressed in lbs. per square inch. DNC – data not collected (due to technical difficulties with the equipment on scheduled examination days)

Table 2.6 – Follow-Up Radiographic Results

ID	Duration	Compliance	T Cobb (deg)	T Rot (%)	T Disc Ind	T Dev. (mm)	L Cobb (deg)	L Rot (%)	L Disc Ind	L Dev. (mm)
1	7 mo.	Poor	65	30	2.09	66	n/a	n/a	n/a	n/a
2	6 mo.	Good	35	10.7	1.43	8	42	13.5	1.24	28
3	5 mo.	Poor	58	26.5	1.5	26.5	48	6.5	1.8	29.5
4	5 mo.	Good	49	13.7	1.75	16	44	17.4	1.4	38
5	7 mo.	Poor	66	20	1.66	55	52	21.4	1.41	32
6	6 mo.	**Fair**	**??**	**??**	**??**	**??**	**??**	**??**	**??**	**??**
7	4 mo.	Fair	31	12.5	1.0	34	17	0	1.27	12.5

T/L Rot – thoracic/lumbar vertebral rotation; T/L Disc Ind – thoracic/lumbar disc index; T/L Dev – thoracic/lumbar apical vertebral deviation; n/a – not applicable

Discussion

Veldhuizen *et al* suggested a two-stage hypothesis that involves neuromuscular factors in the etiology of scoliosis, and biomechanical factors in its progression.[42] As stated before, it is likely that IS is multifactorial. Therefore, it is unlikely there is one etiological agent, and it is possible that different factors may be involved in different cases. This was the reasoning behind a comprehensive approach.

Each part of the protocol is designed to complement each other to address the entire clinical scenario, and is not intended to function in isolation. Primarily, the first phase of treatment addressed soft tissue deformations and improving spinal flexibility, the second phase influenced spinal biomechanics, and the third impacted neuromuscular function.

It has been recognized that wedging occurs in scoliosis first at the disc before the vertebra, and the role of the intervertebral disc (IVD) in the pathophysiology of scoliosis has been discussed previously.[43-47] We used repetitive loading & unloading of the IVD through lateral flexion exercises and passive flexion/distraction therapy in a “mirror-image” configuration to address the physiology of the IVD. In this patient sample, all patients showed positive changes in the thoracic disc indices post-treatment, and four in the lumbar.

Historically, axial spinal traction has been used in various forms as a treatment for spinal deformities.[48] A case report by Chromy *et al* in 2006 used axial spinal traction (LTX 3000™) to reduce Cobb angles in five adolescent girls with scoliosis.[49] Our protocol incorporated axial spinal traction alone and in combination with vibration therapy, lateral traction, and de-rotation, and Cobb angle reductions were observed in all patients in the thoracic spine and six in the lumbar.

Imbalances in the activity of the paraspinal muscles have been recorded in IS; these imbalances are unlikely to be causative, but highly likely to be involved in progression.[50,51] Our goal in including massage therapy as well as in-office and at-home exercises with our protocol was to redress these muscle imbalances and discourage future progression. The benefit of massage in scoliosis was first recorded in 1887,[52] with a recent study providing current data.[53,54] We performed massage on the paraspinal muscles on the convexity of the curvature, and the patient performed rotation exercises aimed at strengthening the paraspinal muscles on the concavity.

The ROM and muscle strength tests and questionnaires provide an indication of functional improvement in this regard.

While scoliosis is characterized primarily by a lateral deviation in the coronal plane,[1] the sagittal spinal profile of individuals with scoliosis has been implicated as a risk factor in its progression.[55] Castelein et al suggested that abnormalities in the sagittal orientation of the vertebrae in humans contribute to the progression of AIS.[56] Millner & Dickson stated that 'the problem is one of front-back asymmetry and not right-left,' and considered the sagittal spinal profile to be of primary pathogenic significance.[57] Cobb angle is considered to be the radiographic "Gold Standard" in the management of scoliosis. While the inter- and intraobserver reliability is good, the accepted standards of measurement error range from 4^{o} to 8^{o}, in part due to the 2-dimensional nature of the analysis.[58-62] We included additional radiographic measurements as they provided more useful clinical data and objective outcome assessment measures to address the patients' scoliosis in all three dimensions.

The CMT techniques used in this protocol focused on addressing the patients' spine three-dimensionally. For example, a typical double-major scoliosis presents with a loss of the cervical lordosis, a loss of the thoracic kyphosis, clockwise axial rotation of the thoracic spine, counter-clockwise axial rotation of the lumbar spine and pelvis, and may present with hyper or hypolordosis of the lumbar spine. The purpose of supine thoracic CMT was to restore the normal thoracic kyphosis and reduce thoracic rotation; prone lumbar CMT, to address the sagittal alignment of the lumbar spine; side-posture pelvic CMT, to address rotation of the pelvis; and, instrument-assisted cervical CMT, to address loss of the cervical lordosis. With this protocol, patients demonstrated reduction in rotation (scoliometry and radiography) and improvement in sagittal spinal alignment (radiography) (although, for the sake of brevity, only the coronal scoliosis radiograph was included with the outcome assessment measures reported in this study).

Proprioceptive and vestibular deficits are commonly recognized in scoliosis.[63-65] The effect of WBV therapy on postural control and sensorimotor function has been researched in the elderly population and in patients with Parkinson's disease,[66-68] but not in adolescents with scoliosis. Our goal in utilizing WBV therapy with our adolescent scoliosis patients was to influence neuromuscular function in a similar fashion. This was combined with reactive body weighting (balance training exercises), in which the patient reacted to strategically positioned weights and cantilevers on the body while standing on an unstable surface, to rehabilitate the postural correction mechanisms.[69] All patients showed improvement in subjective neurological tests; two demonstrated improvement in the TOLSWEC test.

Long-term pulmonary impairment is one of the leading causes of disability in scoliosis.[70] The majority of the patients in this review experienced improvements in several aspects of lung function.

According to SOSORT, cosmesis (aesthetics) and quality of life are ranked as the two most important factors in scoliosis care.[24] The patients in this study experienced objective improvement in both scoliometry and apical vertebral rotation, and subjective improvements in posture as demonstrated through grid photography. Quality of life improvements were noted with the RAND SF-36 and SRS-22 scores, and overall patient satisfaction with the protocol was also favorable as demonstrated by the SRS-22.

According to Brown, pain is reported in 63% of AIS patients when using the methods reported in our study.[71] In this study, the three patients who presented with significant pain reported improvement. The increase in pain (from 1 to 2) in one patient could be attributed to muscle soreness after the two-week intensive physical therapy, CMT, & exercise regime.

Compliance with the at-home exercise regimen appears to have a dramatic influence upon the long-term results of the presented protocol. This is of key importance to the clinician; compliance can be problematic in the adolescent population, and tends to be over-reported.[72,73] In the two patients with poor compliance, both exhibited loss of correction and regressed past pre-treatment levels. The **two** patients with good compliance continued to improve after the conclusion of treatment.

An absent SAR has been reported to be an indicator of underlying spinal cord tethering (syringomyelia, Arnold-Chiari malformation, etc).[74,75] The re-emergence of the SAR in three patients warrants further investigation in future research using MRI and somatosensory evoked potentials (SSEP) as primary outcome measures.

Limitations to this review are recognized by the authors. This is a descriptive review, not an explanatory one. It is a retrospective observational review lacking a control group; there can be no extrapolation beyond the involved subjects. Second, some information was collected by staff other than the authors, and was therefore subject to interpretation. Third, ROM and muscle strength data was incomplete due to failure of the equipment to function properly on the scheduled exam dates. Lastly, it is unknown whether one or all of these individuals would have experienced the same results in the absence of treatment. The chance of spontaneous regression decreases with age and curve magnitude, and the risk of progression in skeletally immature patients with Cobb angles greater than 30 degrees is high, especially in pre-menarchal patients. Five of the seven patients in this review had a Risser sign of 0 or 1; Weinstein and Ponseti in 1983 reported a progression rate of 68% in a similar population.[37]

Conclusion

The clinical and radiographic data indicated an overall improvement in the health status of the patients. The results documented in this review suggest that a multifactorial approach of CMT, massage, exercise, vibration therapy, and neuromuscular rehabilitation may be of benefit in the management of AIS.

Future studies include longitudinal ones to document the permanence of results. Also, prospective studies utilizing adults could eliminate spontaneous regression as a factor. Pragmatic studies are warranted for the clinical setting.

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