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Case Report Open Access

Improved Glycosylated Hemoglobin, Hyperglycemia, and Quality of Life Following Thoracic Hypokyphosis Vertebral Subluxation Correction Using Chiropractic BioPhysics®: A Prospective Case Report

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Abstract

Objective: Spinal misalignment increases spinal cord tension and is linked to various health conditions. There has never been a study on the impact of spinal alignment on blood glucose metabolism. This prospective case with long-term follow-up explores spinal alignment and its impact on type 1 diabetes mellitus.

Case and methods: A 26-year-old male presented with chronic mid-back pain for 9 years and type 1 diabetes mellitus. Radiography and MRI revealed hypokyphosis of the thoracic spine with spinal misalignment from thoracic vertebrae 6 through 9 consistent with vertebral subluxation. Glycosylated hemoglobin and blood-glucose averages were obtained by continuous glucose monitoring. Back pain, paraspinal muscle tension, and quality of life were also measured. The patient received Chiropractic BioPhysics® care including Mirror Image® corrective spinal exercises, adjustments, and traction.

Results: After 36 visits, the patient reported improvement in his mid-back pain and quality of life. Thoracic x-rays showed correction of thoracic hypokyphosis. Surface EMG measuring paraspinal muscle tension improved and continuous glucose monitoring showed dramatic drop in blood glucose immediately following the onset of each visit and improvement in blood glucose averages, percentage of time of blood glucose in a healthy target range, and glycosylated hemoglobin. The patient reported he reduced his basal insulin by approximately half during chiropractic care.

Conclusions: This case suggests that correction of thoracic hypokyphosis using Chiropractic BioPhysics® care protocols may result in improved glycosylated hemoglobin and blood glucose metabolism for a person with type 1 diabetes mellitus, as well as back pain, paraspinal muscle tension, and quality of life.

Keywords: Chiropractic BioPhysics®; Adjustments; Traction; Vertebral subluxation; spine; Type 1 diabetes; Thoracic hypokyphosis; Continuous glucose meter; HbA1c

Introduction

Type 1 diabetes mellitus (T1DM) has serious short-term and long-term health implications. The disorder has a strong genetic component, but the factors that trigger onset of clinical disease remain largely unknown [1]. Hyperglycemia predisposes people with diabetes to serious health conditions and complications such as cardiovascular disease, stroke, nephropathy and kidney failure, retinopathy and blindness, neuropathy, depression, infections and amputations, and premature death [1-11]. T1DM is a disease "with substantial risk of long-term morbidity and mortality. For example, a report from the US Centers for Disease Control [CDC] recently estimated that a 10-year-old boy or girl developing [type 1] diabetes in the year 2000 would lose, on average, 18.7 and 19.0 life-years, respectively, compared with their non-diabetic peers [12]".

There is no known way to prevent or cure T1DM. Advancements in newer treatment approaches have facilitated improved outcomes in terms of both glycemic control and reduced risks for development of complications. Nonetheless, major challenges remain in the development of approaches to the prevention and management of T1DM and its complications [1].

Chiropractic is a health care discipline rooted in the philosophy optimal health and performance is sustained by neurological and spinal health. Conversely, neurological stress and strain contribute to disease and dysfunction and are preceded by abnormal, unhealthy spinal alignment and posture known as vertebral subluxations. Vertebral subluxation involves a biomechanical dysfunction and a neurological compromise [13,14]. This includes rotational or translational displacements of the spine away from normal spinal alignment in any anatomical plane accompanied by neurologic dysfunction. Correction of vertebral subluxations toward a healthy spinal alignment can alleviate the associated pain or neurologic dysfunction [15-18].

Chiropractic is known as a pain-based health care profession; neck pain (NP) and back pain are common presentations in chiropractic practices [19]. However, outside of chiropractic offices, vertebral subluxations remain an under-diagnosed cause of neck and back pain [20]. Many chiropractic techniques claim to produce structural correction of the spine while few are able to support their claims with scientific clinical evidence. "CBP® technique is a full-spine and posture rehabilitation approach to correcting poor posture, deviation of normal spinal alignment and subluxation through incorporating Mirror Image® exercise, adjustments, and traction procedures" [21-25]. Chiropractic BioPhysics® (CBP®) has various quality scientific publications supporting reliable correction of spinal and postural misalignments with correlating neurological, musculoskeletal, and visceral health improvements [15-19,25-31].

There has never been a chiropractic study measuring the impact of correction of spinal misalignment on glycosylated hemoglobin (HbA1c) and blood-glucose metabolism. This is a prospective case study with long-term follow-up showing improvements in HbA1c, blood glucose, mid-back pain, muscle tension, and quality of life following correction of thoracic hypokyphosis vertebral subluxation using Chiropractic BioPhysics® Technique. All procedures performed in this study involving the human participant were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Case and Methods

Clinical features

A 26-year-old male presented to the office with the primary complaint of chronic mid-back pain for nine years as well as a medical diagnosis of T1DM since he was 3 years old. The patient weighed 180 pounds and stood 70 inches tall. The patient reported playing sports throughout his life and collegiate baseball with no history of trauma. The patient confirmed a diet consisting of processed foods high in sugar including donuts, cookies, and soda and was often seen consuming these foods when entering the office. Additionally, the patient confirmed an active social drinking lifestyle. The patient reported that he managed his blood-glucose with insulin therapy via insulin pump. The patient started that he administered a bolus ratio of 10 to 1 at each meal and would administer a basal dose of 6.5 units (U) each day.

The patient rated his mid-back pain as a 7/10 on the numeric rating scale (NRS: 0=no pain; 10=maximum pain). Static surface electromyography (sEMG) was performed using CLA Insight™ Static sEMG, (Chiropractic Leadership Alliance, Bethany Beach, DE, USA). Surface EMG has been established as a valid [32,33] and reliable [34-38] method of measuring amplitude of muscle electrical activity to determine areas of hypo- or hyperactivity associated with neurological and musculoskeletal conditions. Static sEMG indicated moderate and high (severe) elevations in amplitude (tension) of paraspinal muscle activity throughout the thoracic spinal region (Figure 1). Amplitude was recorded at elevations as high as 4.4 times more than normal values at T6 (Table 1).

L Assess 2 (µV)	L Assess 1 (µV)	L Norm (µV)	Site	R Norm (µV)	R Assess 1 (µV)	R Assess 2 (µV)
5.77	4.17	3.8	C1	3.9	5.55	3.94
5.13	4.82	4.4	C3	4.3	6.75	3.83
5.36	4.25	4.2	C5	4.1	3.14	3.95
7.59	4.29	4.8	C7	4.6	5.14	4.56
6.2	11.93	4.9	T1	4.9	5.32	5.31
6.4	21.79	5	T2	5	12.27	4.93
7.31	23.79	6.5	T4	6.4	18.48	5.66
6.66	28.35	8.4	T6	8.2	31.26	5.8
10.6	19.39	9.6	T8	9.5	21.2	6.9
10.74	14.83	10	T10	10	18.65	6.93
11.2	13.8	9.8	T12	9.8	17.17	6.93
12.86	10.21	8.7	L1	8.7	11.67	7.8
11.2	17.54	6.1	L3	6.2	23.97	6.53
9.31	6.37	5.2	L5	5.3	7	6.05
4.95	12.69	4.4	S1	4.4	14.34	4.14

µV: microvolts; Site: Location of the vertebra where paraspinal electrical amplitude was assessed; L Assess: Left Assessment; R Assess: Right Assessment

Table 1: sEMG Analyses at Initial Visit versus After 36 Visits (7 Weeks).

Using Health and Wellness Score (FLDC, LLC, Cumming, GA, USA) to administer, score, and analyze the Short Form 36-Question (SF-36) health survey, the patient scored a 100/100 in physical function (PF), 25/100 in physical role limitations (PRL), 33.33/100 in emotional role limitations (ERL), 75/100 in vitality (V), 88/100 in emotional well-being (EWB), 100/100 in social functioning (SF), 57.5/100 in pain (P!), 35/100 general health (GH), and 50/100 in change in health status (ΔHS) (Table 2). The scoring of the SF-36 indicates that 0/100 represents the poorest possible result and 100/100 indicates the best possible result in any quality of life (QoL) domain.

#	PF	PRL	ERL	V	EWB	SF	P!	GH	ΔHS
1	100	25	33.33	75	88	100	57.5	35	50
2	100	75	100	85	92	100	67.5	55	100
3	100	100	100	85	88	100	80	50	50

PF: Physical Functioning; PRL: Physical Role Limitations; ERL: Emotional Role Limitations; EWB: Emotional Well-Being; V: Vitality; SF: Social Functioning; P!: Pain; GH: General Health; ΔHS: Change in Health Status

Table 2: Health and Wellness Score SF-36 QoL Analyses at Initial Visit versus After 36 Visits (7 Weeks) versus 16 Month Follow-up Assessments. This 36-Item Health Survey was developed at RAND as part of the Medical Outcomes Study.

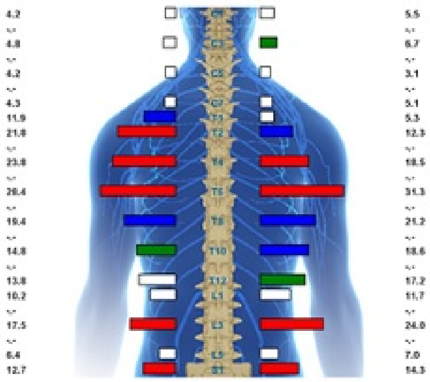

Figure 1: Paraspinal sEMG at Initial Visit . White bars indicate WNL of elevation in amplitude (tension) of paraspinal muscle electrical activity; Green bars indicate mild elevation in amplitude (tension) of paraspinal muscle electrical activity; Blue bars indicate moderate elevation in amplitude (tension) of paraspinal muscle electrical activity; Red bars indicate high elevation in amplitude (tension) of paraspinal muscle electrical activity.

Continuous glucose monitor

The patient was using the Dexcom® G4 Platinum Professional continuous glucose monitoring (CGM) system (Dexcom®, Inc, San Diego, CA, USA). CGM is FDA-approved and shows blood-glucose readings every 5 minutes in real time. Dexcom® CGM consists of 3 parts: a small sensor that measures glucose levels is injected just underneath the skin; a transmitter attached to the top of the sensor that sends data wirelessly to the receiver; and the receiver that displays blood-glucose levels and trends. CGM tracks the rate, levels, and direction of glucose metabolism. During the week prior to chiropractic care, the CGM recorded a blood glucose average of 175 mg/dL (target range is 80 to 180 mg/dL) with a standard deviation of + 71 mg/dL. The CGM reported that the patient's blood glucose remained in the high, target, and low ranges 41%, 53%, and 6% of the time, respectively (Figure 2, Table 3). The CGM also reported hemoglobin A1C (HbA1c, A1c). HbA1c determines the amount of glucose attached to hemoglobin, the protein in red blood cells (RBC) that carries oxygen. Because RBCs live for about 3 months, the HbA1c test reflects average blood glucose levels over the past 3 months. HbA1c is reported as a percentage; below 5.7% (39 mmol/mol) indicates normal, 5.7-6.4% (39 to 46 mmol/mol) indicates a prediabetes diagnosis, and 6.5% (48 mmol/mol) or more indicated a diabetes diagnosis [39]. After the initial 14 days of using the CGM, it showed the patient's HbA1c was 7.7% (61 mmol/mol) prior to care (Table 3).

Week	Normal Range (mg/dL)	Glucose Average (mg/dL)	Standard Deviation (mg/dL)	% Time in High Range	% Time in Target Range	% Time in Low Range	Hemo globin A1C (%)	Hemo globin A1C mmol/mol)	C-peptide (L)
1*	80-180	174	71	39	55	6	7.7	61	
2*	80-180	178	72	47	46	7	7.7	61	
3#	80-180	157	60	31	63	7			
4#	80-180	154	57	33	61	6			
5#	80-180	151	46	26	70	4			
6#	80-180	159	71	34	54	12			<0.10
7#	80-180	144	66	25	63	12			
8#	80-180	144	52	24	66	10			
9#	80-180	150	52	24	69	6	6.7	50	<0.10
10*	80-180	166	57	36	59	5			
70*	80-180						6.1	43	

*: Cells this mark indicate when the patient was not receiving chiropractic care; #: Cells this mark indicate when the patient was receiving chiropractic care; mg/dL: milligrams per deciliter; HbA1c: Hemoglobin A1c test for percentage of glucose attached to hemoglobin; mmol/mol: Hemoglobin A1c measurement in millimoles per mole; L: Liter

Table 3: CGM and Blood Test Readings at Initial Visit versus After 36 Visits (7 Weeks) versus 16-Month Follow-up Assessments.

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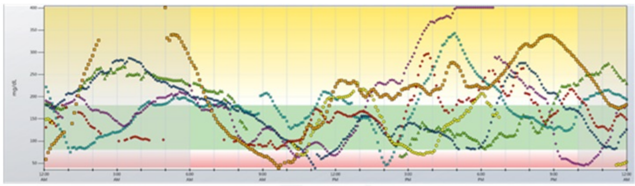

Figure 2: CGM For 7 Days Prior to Chiropractic Care.

Postural and radiographic analysis

Opposing thoracic radiographs were taken and analyzed using PostureRay® Electronic Medical Records (EMR) Software (PostureCo, Inc., Trinity, FL, USA) according to the Harrison Posterior Tangent method for sagittal spine views [22] and analyses for frontal spine views. These examination and analysis methods have established validity [40-42], reliability and repeatability [43-45] as does posture [46]. The anterior-to-posterior (AP) thoracic view revealed a spinal alignment within normal limits (WNL).

Measurement	Normal Values	X-ray 1 Values	X-ray 2 Values	X-ray 3 Values
RRA T2-T3	4.0°	0.1°	3.5°	4.2°
RRA T3-C4	5.0°	3.1°	4.9°	2.0°
RRA T4-T5	6.0°	0.4°	4.0°	4.0°
RRA T5-T6	5.0°	8.0°	5.6°	4.4°
RRA T6-T7	6.0°	5.1°	4.5°	5.8°
RRA T7-T8	6.0°	2.4°	5.5°	4.1°
RRA T8-T9	4.0°	-2.5°	3.1°	3.0°
RRA T9-T10	3.0°	1.0°	3.0°	2.4°
RRA T10-T11	3.0°	7.3°	4.0°	5.5°
ARA T6-T9	16.0°	5.0°	13.1°	12.9°
ARA T2-T11	42.0°	24.9	38.1°	35.4°

RRA: Relative rotational angle; the angle measurement of the lines tangent to the posterior aspect of two adjacent vertebrae listed following RRA; ARA: Absolute rotational angle; the angle measurement of the lines tangent to the posterior aspect of two vertebrae at the limits of a spinal region listed following RRA.

Table 4: PostureRay® EMR Initial Visit versus After 36 Visits (7 Weeks) versus 16 Month Follow-up Radiographic Analyses.

The Lateral thoracic (LT) view (Figure 3) revealed a relative rotational angle from T8 to T9 (RRA T8-T9) of -2.5° (ideal is 4.0°), an absolute rotational angle from T5 to T9 (ARA T5-T9) of 11.1° (ideal is 21.0°), and an ARA T2-T11 of 25.7° (normal is 42.0°) (Table 4). These analyses indicate a reversed curvature or lordosis at T8-T9 and a hypokyphosis from T5-T9 and T2-T11.

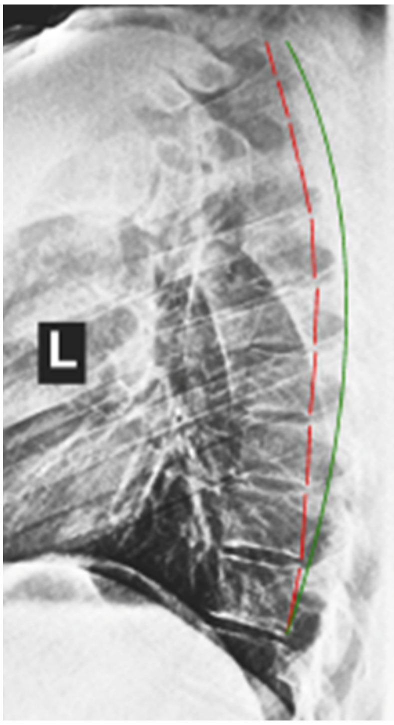

Figure 3: LT X-ray at Initial Visi. The green line represents the Normal Spinal Position and expected path of the posterior longitudinal ligament; The red line represents the patient's position known as George's Line. This is the path of the posterior longitudinal ligament.

Magnetic resonance imaging (MRI)

An MRI was obtained of the thoracic spine (Figure 4). Multilevel chronic Schmorl's nodes, especially from T10 through T12, were noted. Disc desiccation was greatest at T8-T9 and T10-T11. Disc space narrowing appeared greatest at T10-T11 and T11-T12. There was facet hypertrophy on the right at T9-T10. Thoracic disc displacement was most notable at T10-T11 with generalized disc bulging and a very small central disc herniation.

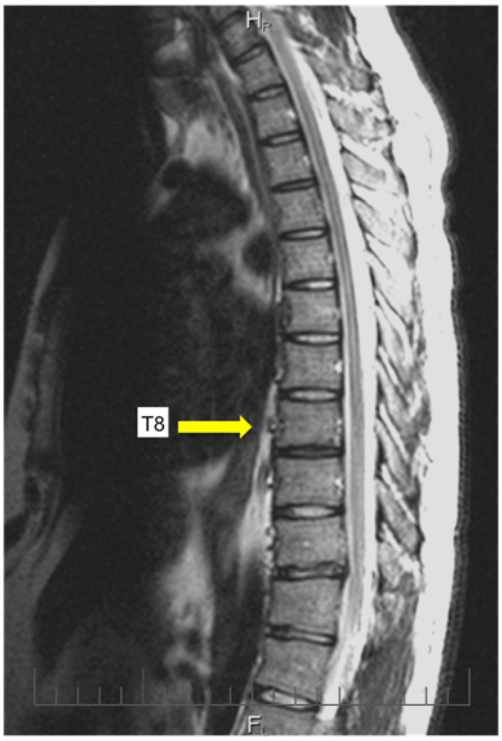

Figure 4: LT View of MRI at Initial Visit.

Intervention

The patient was seen for 36 visits over 7 weeks per CBP® technique protocols using Mirror Image® exercises, adjustments, and traction to correct the thoracic lordosis and overall hypokyphosis. The patient was not being treated for T1DM. The patient was not advised to alter any treatments or therapies for his T1DM. The patient was being treated for vertebral subluxation and spinal misalignment and dysfunction. Chiropractic care consisted of full-spine chiropractic adjustments and CBP® Mirror Image® drop table adjustments, exercises, and traction at each visit. Using Mirror Image® protocol, the patient was placed into an over-corrected posture for adjustments, exercises, and traction to facilitate spinal alignment and posture correction. The hand-held Impulse® adjusting instrument (Neuromechanical Innovations, Chandler, AZ, USA) was used to apply spinal and paraspinal mechanical impulses [47]. The Impulse® adjusting instrument delivers a consistent programmed mechanical thrust to stimulate mechanoreceptors and proprioceptors to relay the position of the body to the brain to retrain the patient's central nervous system (CNS) to adapt to normal posture according to the Harrison Spinal Model. Twenty repetitions of Mirror Image® thoracic flexion correction exercises were performed at each appointment. Mirror Image® exercises "attempt to re-train the physiologic adaptations of the soft tissues of the spine by frequently stressing these tissues favoring the optimum loading position balance [48]". The Erickson Traction Fulcrum (Circular Traction Supply, Inc., Huntington Beach, CA, USA) and CBP® Mirror Image® Blocks (CBP Seminars, Inc., Meridian, ID, USA) were used for thoracic flexion traction at 15 minutes per session with one session per appointment. Deformation forces over a long period of time counter habituated abnormal posture [15-18]. The fulcrum and blocks are used to apply a counterforce against the direction of spinal misalignments. Gravity forces the body against the fulcrum and blocks and additional straps aid in additional force against the blocks to increase the intensity of the counterforce as the patient's tolerance increases.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Average Blood Glucose Level (mg/dL)	130.6#	164.4*	149.9#	146.4#	149.7#	149*	161.5*
*: Cells this color indicate when the patient was not receiving chiropractic care; #: Cells this color indicate when the patient was receiving chiropractic care; mg/dL: milligrams per decilitre.							

Table 5: CGM Average Blood Glucose Levels per day During 7 weeks of Chiropractic Care.

Outcomes after 7 weeks of chiropractic care

The patient stated that he maintained his lifestyle throughout chiropractic care. The patient was reassessed after the 36 visits. LT x-ray (Figure 5) analysis (Table 4) after the 36 visits revealed improvements in RRA T8-T9 from -2.5° to 3.1° (ideal is 4.0°), ARA T6-T9 from 5.0° to 13.1° (ideal is 16.0°), and ARA T2-T11 from 24.9° to 38.1° (normal is 42.0°). The patient reported that his mid-back pain was reduced from NRS 7/10 to 4/10. Static sEMG was performed again and the patient showed improvements in amplitudes of paraspinal muscle electrical activity from severe readings to mild and mostly WNL readings (Figure 6, Table 1). On the SF-36, the patient showed maintenance or improvement in QoL domains (Table 2).

During the last week of chiropractic care, the CGM recorded an improved blood glucose average of 142 mg/dL with a standard deviation of + 52 mg/dL. The CGM reported that the patient's blood glucose remained in the high, target, and low ranges 22%, 67%, and 11% of the time, respectively (Figure 7, Table 3) and the patient's HbA1c improved to 6.7% (50 mmol/mol) (Table 3). Interesting to note, the CGM showed an average decrease in blood glucose of 81.6 mg/dL at the onset of each Mirror Image® traction session throughout care with an average lasting time of approximately 3 hours before increasing again. Additionally, during the 7 weeks of chiropractic care, the CGM showed a marked decrease in average blood glucose of 14.5 to 33.8 mg/dL on the days the patient received chiropractic care versus the days he did not (Table 5). The patient also reported that he reduced his basal insulin dosage from 6.5U to 3U during week 4 of care. He stated that he was able to keep that dosage throughout the remainder of his care. When the patient was released from chiropractic care after the 7 weeks, he discontinued the use of the CGM.

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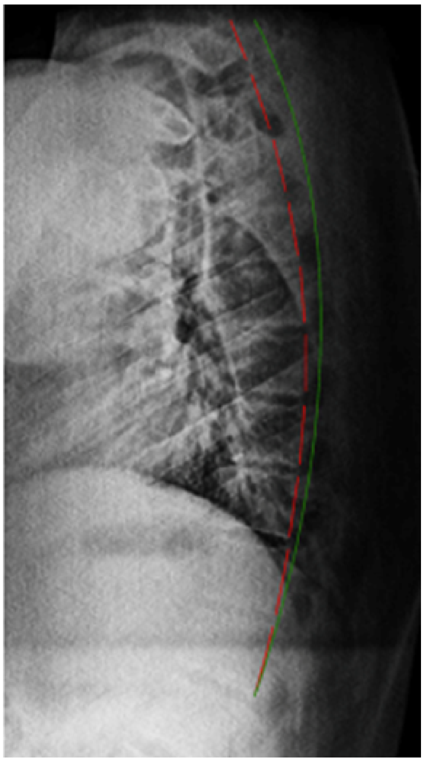

Figure 5: LT X-ray after 36 Visits (7 Weeks). The green line represents the Normal Spinal Position and expected path of the posterior longitudinal ligament; The red line represents the patient's position known as George's Line. This is the path of the posterior longitudinal ligament.

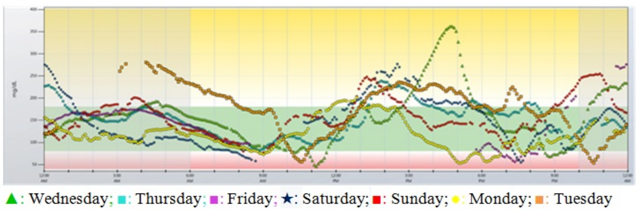

Figure 6: CGM For Last 7 Days of Chiropractic Care.

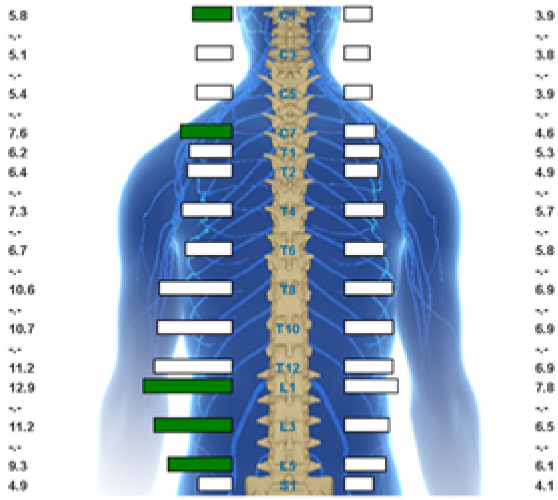

Figure 7: Paraspinal sEMG after 36 Visits. White bars indicate WNL of elevation in amplitude (tension) of paraspinal muscle electrical activity; Green bars indicate mild elevation in amplitude (tension) of paraspinal muscle electrical activity; Blue bars indicate moderate elevation in amplitude (tension) of paraspinal muscle electrical activity; Red bars indicate high elevation in amplitude (tension) of paraspinal muscle electrical activity.

Outcomes at long-term follow-up assessment 16 Months following chiropractic care

The patient was reassessed 16 months following chiropractic care. The patient stated that he did not change lifestyle habits from prior to his chiropractic care through long-term follow-up assessment. LT x-ray (Figure 8) analysis (Table 4) 16 months after chiropractic care revealed maintained improvements in RRA T8-T9 from 3.1° to 3.0° (ideal is 4.0°), ARA T6-T9 from 13.1° to 12.9° (ideal is 16.0°), and ARA T2-T11 from 38.1° to 35.4° (normal is 42.0°). The patient reported that his mid-back pain maintained a reduction from NRS 4/10 to 4/10. On the SF-36, the patient showed maintenance or improvement in QoL domains (Table 2). A blood test showed the patient's HbA1c further decreased to 6.1% (43 mmol/mol) (Table 3). The patient also reported that he was able to maintain the reduced basal insulin dosage of 3U at 16-month follow up.

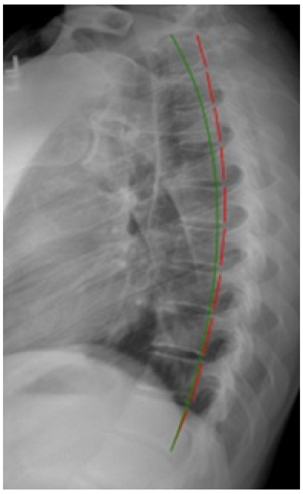

Figure 8: LT X-ray at 16-Month Follow-up. The green line represents the Normal Spinal Position and expected path of the posterior longitudinal ligament; the red line represents the patient's position known as George's Line. This is the path of the posterior longitudinal ligament.

Discussion

This report documents the successful outcomes in a 26-year-old patient with mid-back pain and T1DM as well as unhealthy spinal alignment and posture and paraspinal muscle tension. Improvements in symptoms were achieved following the correction of thoracic spinal alignment using CBP® technique and the application of Mirror Image® chiropractic adjustments, spinal exercises, and spinal traction using CBP® Mirror Image® Blocks.

Certain circumstances and concurrences need to be highlighted within this report. The patient did not alter his lifestyle throughout or following care. It is remarkable that he continued to consume processed foods high in sugar and still yielded the extraordinary health improvements documented. The patient stated that chiropractic care was the only change in his everyday routine. During and following correction of the thoracic spinal alignment, the patient yielded significant improvements in blood glucose levels and HbA1c (Table 3).

Biomechanics, neurology, and dysautonomia

An action potential along the spinal cord and nerves is accompanied by shortening and swelling of the nerve [49]. Sagittal spinal deformities and vertebral subluxations apply abnormal tensile forces in the brain stem, cranial nerves 5-12, spinal cord, and nerve roots. Increased tension resists shortening and swelling of nerve fibers that accompany an action potential. This tension can give rise to local and distant signs and symptoms including neuralgias, spasticity, dizziness, bladder dysfunction, cervical and lumbar spondylosis, disk hernias, trauma to the spinal cord, and autoimmune disorders [15-18,27-29,50]. Additionally, according to Uchida et. al, "adequate correction of local sagittal alignment may help to maximize the chance of neurological improvement [48]". This serves as a proposed mechanism for the source of this patient's health improvements following sagittal thoracic spinal correction.

Presynaptic sympathetic nerves that innervate the pancreas arise from cell bodies of the intermediolateral (IML) nucleus of the spinal cord located at spinal cord segments T6 through T9. As such, T6 through T9 sagittal alignment was noted in this report as well as any remarkable findings in that anatomy including the reversed RRA T8-T9. These nerve fibers travel via "spinal nerves, anterior rami, and white communicating branches to the sympathetic trunks, continue as components of abdominopelvic splanchnic nerves [and] pass to prevertebral ganglia. After synapsing with the ganglia, the post-synaptic sympathetic nerves travel to the [pancreas] conveying sympathetic innervation [51]".

Various studies have investigated the relationship between spinal dysfunction and increased sympathetic tone [52-54], which has been linked with immune dysfunction and reduced health [55,56]. In a study of 50 cadavers with 139 diseased organs, Windsor found that the 100% of the diseased organs belonged to the same sympathetic segment as an affected vertebra found to be out of normal spinal alignment [55]. The results of a study of 12 men suggests that chiropractic care affects regional glucose metabolism related to sympathetic relaxation [inhibition] and pain reduction [57]. "The sympathetic nervous system (SNS) plays a significant role in metabolic function and coordination of glucose homeostasis. In the pancreas, sympathetic activation inhibits insulin release and increases glucagon secretion [58]".

In this case, x-rays showed that the patient's T6 through T9 spinal alignment was extended in neutral, standing posture. CGM readings during thoracic flexion traction showed that blood glucose metabolism was markedly increased as a result.

Initial x-ray and MRI findings confirm the degenerative effects of loss of sagittal curvature in the spine which serve as shock absorbers. With decreased shock absorption in the thoracic spine, the functional spinal unit is subjected to increased force. As such, degeneration occurs consistent with Wolff's law of bone adaptation and Davis' Law of soft tissue adaptation. "With mal-alignment in neutral posture, static and especially dynamic function from this mal-alignment dictates altered stress/strain relationships of associated spinal structures, including the bones, intervertebral discs, facet joints, musculotendinous tissues, ligamentous tissues, and neural elements [22]".

Reassessment x-rays confirmed that the patient's T6 through T9 spinal alignment had been corrected and blood testing showed that the HbA1c improved during and following care and continued to improve while correction of the thoracic spine was maintained. This is particularly important as the Diabetes Control and Complications Trial (DCCT) shows that a person's ability to maintain glycemic control significantly reduces his risk of complications and comorbidities associated with T1DM and that "achieving reduced HbA1c concentrations, continue to have greater protection against development or progression of complications [12]". The continued improvement in HbA1c may be a part of the body's natural healing process. A fractured bone has not fully healed neither upon setting of the bone nor casting of the bone nor removal of the cast. Rather, the bone continues to heal well beyond removal of the cast.

Strengths and Limitations

One limitation to report is that this is a case study (n=1). However, the prospective design of the case study paired with a long-term follow-up assessment provide added strength to the case. As a prospective case study, it does not lend itself to selection bias. The 16-month follow-up after cessation of chiropractic care helps to determine the lasting effectiveness of the care administered. Another limitation is that various interventions were applied to the patient. As such, it is uncertain which intervention or combination of interventions had the positive effect on the patient's health measures. And, while spinal manipulation and exercise have not been shown to reliably correct spinal alignment [25,59-61], there may be a reliable combination of therapies within permutations of Mirror Image® exercises, adjustments, and traction [15-18].

Improvement of HbA1c is clinically significant. The DCCT and the United Kingdom (UK) Prospective Diabetes Study have found that any interventions done to improve the HbA1c levels in diabetics directly decreases the risk of complications related to T1DM [62,63].

Conclusion

This case adds more evidence to claims that thoracic spinal alignment may also improve paraspinal muscle tension, QoL, and mid-back pain. As thoracic spinal alignment improved, so too did the listed health measures. This case also suggests, for the first time, that thoracic spinal alignment may be related to blood glucose metabolism and that correction thereof may influence blood glucose metabolism as represented by HbA1c and CGM blood glucose measurements. Spinal analysis and care may benefit people with T1DM in terms of glycemic control and aid in screening for T1DM early detection. Diabetes researchers have emphasized the need to perfect the prediction model for T1DM "and to develop effective and safe interventions that reverse the condition either in its preclinical or early clinical phase [12]". Additionally, researchers are looking for novel treatment strategies to achieve normoglycaemia. "Although insulin analogues and insulin pumps help more physiological insulin replacement approaches to be developed, they remain imperfect because of factors other than insulin that affect glycaemia [12]". Randomized clinical controlled trials involving measuring thoracic spinal alignment and HbA1c and CGM blood glucose measurements of a large population of people with T1DM should be conducted. This case report will serve as a motivation for higher levels of evidence from which correlations and causations regarding the effects that chiropractic spinal corrective care might have on blood glucose metabolism can be made.

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Compliance with Ethical Standards

Disclosure of potential conflicts of interest

Drs. Curtis Fedorchuk, Douglas F. Lightstone, Robert D. Comer, and Michael T. Weiner are chiropractors who practice using Chiropractic BioPhysics® protocols. Drs. Curtis Fedorchuk and Douglas F. Lightstone are officers of the ISHP which funded this paper. Dr. Robert D. Comer is a member of the ISHP. Drs. Curtis Fedorchuk and Matthew McCoy are officers of the FVS which funded this paper. Dr. Douglas F. Lightstone has a research fellowship through the FVS.

Research involving human participants and/or animals

All procedures performed in this study involving the human participant were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study. Additional informed consent was obtained from all individual participants for whom identifying information is included in this article. The participant was a patient in a private chiropractic practice and provided informed consent for publication of the results of his case.

Informed consent

This study was reviewed for Human Subjects Protection and approved by the Independent Review Board of the Foundation for Vertebral Subluxation. The participant was a patient in a private chiropractic practice and provided informed consent for publication of the results of his case.

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