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Case Study

Non-surgical reduction in thoracolumbar kyphosis and sagittal vertical axis corresponding with improved sensorimotor control in an older adult with spinal deformity: a Chiropractic Biophysics® case report

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Abstract. [Purpose] We document the significant improvement in posturography and spinal deformity by Chiropractic BioPhysics® (CBP®) technique methods. [Participant and Methods] A 78-year-old male presented with 20 years of chronic hip and lower back pain and stiffness. The pain was 5/10 and disability was 38%. The patient also complained of walking difficulty and balance problems. Radiographic assessment demonstrated a significant thoracolumbar kyphosis and anterior C7-S1 sagittal vertical axis (SVA). Force plate posturography showed high centre of pressure (COP) parameter values including the total path length, particularly for the vestibular condition of the modified clinical test of sensory integration and balance (mCTSIB). [Results] The patient was treated with 36 sessions of CBP corrective exercises and spinal traction as well as PowerPlate balance and gait exercises. Assessment after 4-months showed improvements in sleep, pain, disability, and mobility. There was a 79 mm reduction in SVA and improved postural control in many parameters including a 49 cm and 22 cm reduction in COP total path length for the vestibular and visual trials on the mCTSIB, respectively. The pain and disability were reduced to 0/10 and 22%. [Conclusion] This case demonstrates the significant improvement in postural control as quantified by the mCTSIB with the reduction of excessive SVA as demonstrated on post-treatment x-rays.
Key words: Thoracolumbar kyphosis, Sagittal vertical axis, Postural control

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INTRODUCTION

Adult spinal deformity (ASD) is an idiopathic and/or degenerative condition of the adult spine leading to a deformity in the coronal and/or sagittal plane that affects the thoracolumbar spine throughout the ageing process[1)]. It is well established that ASD is a disorder having significant clinical ramifications including pain, disability, loss of independence, reduced quality of life, cognitive decline and premature mortality[2–7)].

Although ASD is definitively associated with disability[8, 9)], recent evidence suggests that the relationship between radiographically measured spinopelvic variables and health-related quality of life (HRQOL) measures are relatively weak and that spinal deformity may not be the main driver of patient-reported outcomes (PROs)[10–12)]. Boissiere and colleagues, for example, found that demographics, including age, gender, BMI, past surgery, and being a surgical or non-surgical candidate, accounted for 40% of explained variance in disability (Oswestry index) in a sample of ASD patients, and that the radio-

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graphic parameters used in their study (global tilt; lumbar lordosis index) only added an extra 1.5% of explained variance[10]. Further, Chapman and colleagues found only weak correlations between radiographic parameters and PROs in a sample of adult symptomatic scoliosis patients and concluded that there must be other factors contributing to PROs[12]. Together, these studies illustrate a disconnect between radiographic and PROs that may mask a more complete understanding of the impact of ASD on disability.

As opposed to static X-ray measures, functional performance tests may be more relevant to clinical outcomes, and have been found to be an important clinical correlate to disability in the assessment of ASD. Lee et al., for example, determined a set of functional tests correlated more strongly with HRQOL than did X-ray parameters (with the exception of the C7 to S1 sagittal vertebral alignment (SVA)), and suggested that functional mobility testing may play a bridging role between static radiographic parameters and subjective PROs when managing ASD patients[13]. With respect to balance testing, Moke and colleagues found that balance assessment by use of the balance evaluation systems test (BESTest) had a higher prediction value versus both X-ray measures and demographic variables to predict HRQOL in a group of ASD patients[14].

The assessment of ASD involves both the documentation of deformity parameters from X-rays as well as a comparison to established thresholds important for long-term outcomes[1–3]. The SVA for example, is considered significant if greater than 40 mm, and is considered excessive if greater than 95 mm[15]; these are considered clinically important cut-offs for diagnosing and classifying deformity patients. Importantly, as mentioned, there is an association between ASD and postural balance control; however, it is only recently that posturography, or the measurement of the center of pressure (COP) by assessment of standing on a force plate[16] has been incorporated into clinical practice as the technology has evolved allowing force plates to become portable, economical and easily incorporated into daily practice[17]. The reporting of deformity reduction in ASD in combination with a documented improvement in postural balance control is rare[18]. Thus, the purpose of this case report is to document the improvement in postural balance control in conjunction with a reduction in SVA and thoracolumbar kyphosis spinal deformity by non-surgical Chiropractic BioPhysics® (CBP®) technique methods.

PARTICIPANT AND METHODS

This report was conducted as part of a quality improvement process to add objective quantification of standing balance to routine practice following CBP techniques (TCPS2, Sec. 2.5)[19]. On October 17, 2022, a 78-year-old male (height: 183 cm; weight: 77 kg) presented with chronic hip and lower back pain (LBP) and stiffness. The pain was rated as averaging a 5/10 on an 11-point numerical pain rating scale (NPRS)[20]. The patient scored 38% on the Oswestry low back pain questionnaire (ODI) indicating a moderate-severe disability rating[21]. The patient also complained of walking difficulty and balance problems that he attributed to a previously diagnosed right leg nerve entrapment, but denied any radiculopathy into the leg or foot. The LBP was described as a dull ache and stiffness being present for more than 20 years. There was no history of falling or any other report of sensory or proprioception problems. The patient wore corrective glasses that were updated regularly. Aggravating factors included getting out of bed, prolonged sitting, standing or driving and relieving factors included movement and exercise. In fact, the patient described being physically active 5 days per week performing combinations of stretches, stationary bike and/or rowing for 10-minutes per session, motivated by his back and hip ailments. The patient's personal health goals were to be able to sleep better, walk better, and to improve his standing balance. There were limited previous treatments, but none gave significant relief.

A visual assessment of gait and posture revealed that the patient had a forward stoop (increased SVA) and this persisted while walking. The patient had a visible flexion deformity (hyperkyphosis) throughout the middle to lower back as well as forward projected head translation. Range of motion assessment showed a marked decrease in flexibility in all directions for the neck and back; in fact, there was little movement at all for low back twisting and bilateral bending. Palpation of the paraspinal muscles indicated tight muscles bilaterally along the length of the whole spine. Lower extremity manual muscle testing revealed reduced strength in hip extension as well as toe and heel walking. The right calf displayed mild atrophy from nerve entrapment. The straight leg raise test was limited bilaterally due to inflexibility but not referred pain. The Patrick-FABERE and femoral nerve stretch tests both demonstrated excessive inflexibility of the hip joints bilaterally.

A recent (Dec. 21, 2021) multiplanar multisequence MRI of the lumbar spine revealed multilevel degeneration throughout the lumbar spine. Specifically, there were varying degrees of intervertebral disc height loss, multilevel vertebral body osteophyte formation and scattered Modic type II endplate degenerative changes throughout the entire lumbar spine ranging from T12-S1. A recent (Dec. 3, 2021) MRI of the hip joints revealed bilateral hip joint space narrowing (left being greater than the right), left (minimal) and right (mild) marginal articular ring osteophytosis as well as right superior lateral femoral head and neck flattening. The latter finding was indicative of possible femoro-acetabular impingement which can lead to hip pain secondary to the mechanical impingement from abnormal hip morphology involving the acetabulum and/or proximal femur[22]. Over time, accelerated osteoarthritis of the hip joint usually occurs.

Full-spine standing radiographic imaging of the spine was taken from the cervical spine to the femur heads as per standard ASD assessment[23]. The images were imported into the PostureRay EMR software (PostureCo Inc., Trinity FL, USA) which allows digitization of the individual images. The Harrison posterior tangent method of intersegmental angle mensuration[24–27] is integrated within the program and has a small standard error of measurement (~2°). The radiographic assessment of the current patient demonstrated a predominant thoracolumbar kyphosis (Cobb T10-L2=29.1°) and exaggerated anterior sagittal vertical axis (SVA: C7 centroid to posterior-superior corner of S1=72.8 mm) (Fig. 1).

The BTrackS (BTS) portable force plate (www.balancetrackingsystems.com)[28] was used to assess the patient's standing balance (Table 1). The BTS has been found to have similar performance relative to a lab grade force plate and has excellent reliability[18, 29, 30]. The BTS collects COP data which is the location of the vertical ground reaction vector and reflects the neuromuscular response to changes in the position of the center of mass (CM)[31]. The COP is measured in the anteroposterior and mediolateral directions for which many standard COP parameters can be calculated[32, 33].

The modified clinical test of sensory integration and balance (mCTSIB) is a modified test based on the pioneering work of Shumway-Cook and Horak[34] and was used to isolate and assess the different sensory subsystems of balance performance. The mCTSIB consists of 4 trials, the first two trials involve standing on the firm plate, the last two trials involve standing on a foam surface (Fig. 2)[35]. Trials 1 and 3 were performed with the eyes open (EO) and trials 2 and 4 were performed with the eyes closed (EC). Thus, the test challenges different sensory inputs and are referred to as the control condition (trial 1), somatosensory condition (trial 2), visual condition (trial 3) and vestibular condition (trial 4), so named according to the sensory system that dominates each particular condition[35]. The mCTSIB involves four single 20 second trials and has

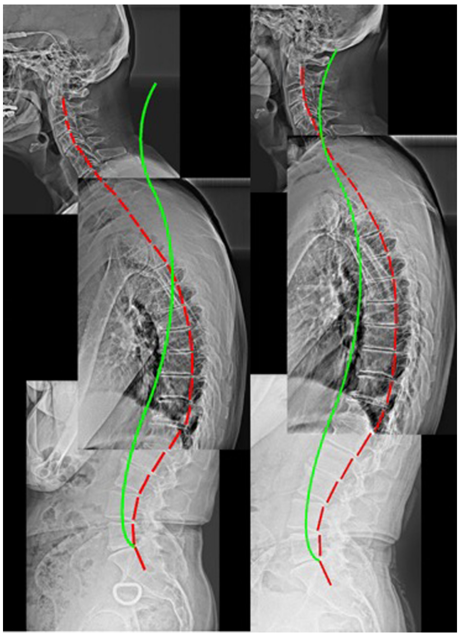

Fig. 1. Full-spine lateral radiographs.
Left: Patient has thoracolumbar junctional kyphosis and exaggerated forward lean of the thorax and head. Right: Post-imaging shows reduction in deformities. Green line indicates ideal alignment; red lines indicate vertebral posterior tangents.

Table 1. Pre- and post-treatment center of pressure (COP) parameters for the four trial conditions from the modified clinical test of sensory integration and balance (mCTSIB)

mCTSIB Trial conditions		COP PL (cm)	95% Area (cm^2)	Avg. Velocity (cm/s)	RMS ML (cm)	RMS AP (cm)
1. Standard	Pre	34	1.2	1.7	0.2	0.4
(firm–EO)	Post	44	2.2	2.2	0.2	0.5
2. Proprioception	Pre	61	2.3	3	0.2	0.6
(firm–EC)	Post	58	3.1	2.9	0.3	0.6
3. Visual	Pre	86	9.6	4.3	0.7	0.7
(foam–EO)	Post	64	5.3	3.2	0.5	0.6
4. Vestibular	Pre	164	37	8.2	1.4	1.4
(foam–EC)	Post	115	17.1	5.7	0.8	1.1

AP: anterior-posterior; EO: eyes open; EC: eyes closed; ML: medial-lateral; PL: path length; RMS: root mean square; Avg: average. Trial conditions are named according to the dominant sensory system presumed to contribute to postural steadiness.

established test-retest reliability[35] as well as normative data published for the calculated COP total path length[36–38]. Table 1 illustrates the results from the mCTSIB. In general, values for all metrics, including the COP path length, 95% ellipse area, average velocity, root mean square (RMS) in the ML and AP directions, increased across trials 1 to 4. Notably the COP path length for the vestibular condition was below the 20th percentile for older adults aged 60+ years[38]. The 95% ellipse area plots are shown in Fig. 3 and demonstrate the increase in area across trial conditions.

The patient was treated using variations of CBP technique methods to reduce the exaggerated SVA. CBP technique involves exercises, adjustments and traction methods that are directed in the opposite direction to the spinal deformity (subluxation pattern)[39–42]. The patient was initially treated three times per week but for various reasons missed sessions resulting in 36 treatments over a 4-month period. No timeline is presented as this is a simple pre-post report.

Exercises included five back extension 'corrective' exercises aimed at hyperextending the thoracolumbar spine (Fig. 4). Exercises included the bird dog, superman, standing W's, standing horizontal arm extension with resistance and a head/pelvis posterior translation exercise. All exercises were performed during whole body vibration (WBV) on the PowerPlate (www.powerplate.com) platform to intensify exercise effects[43] except the head/pelvis posterior translation exercise was performed with the back to a wall (50 repetitions, holding for 3-count). Two additional PowerPlate exercises included walking in place, while raising the knees to 90° and squats (not bending knees beyond 90°). All PowerPlate exercises were performed for 60 second durations.

Spinal traction consisted of a thoracolumbar extension traction in a seated position (Fig. 5). This was performed for 10-minutes per session. The amount of pull was increased to maximum tolerance as treatments progressed. The patient was also prescribed home traction where he lay supine over a firm convex lumbar support positioned so the peak of the support was centered to the T12 area. This was performed 10-minutes per day on the days the patient did not attend treatments

Fig. 2. The modified clinical test of sensory integration and balance (mCTSIB).
Trial 1: all sensory inputs available; Trial 2: vision is excluded resulting in reliance of proprioceptive input from the feet; Trial 3: Proprioceptive inputs are challenged resulting in reliance from visual input; Trial 4: vision is excluded and proprioception from the feet is challenged forcing reliance on the vestibular system. The mCTSIB is a modification of the pioneering work of Shumway-Cook and Horak (1986)[34].

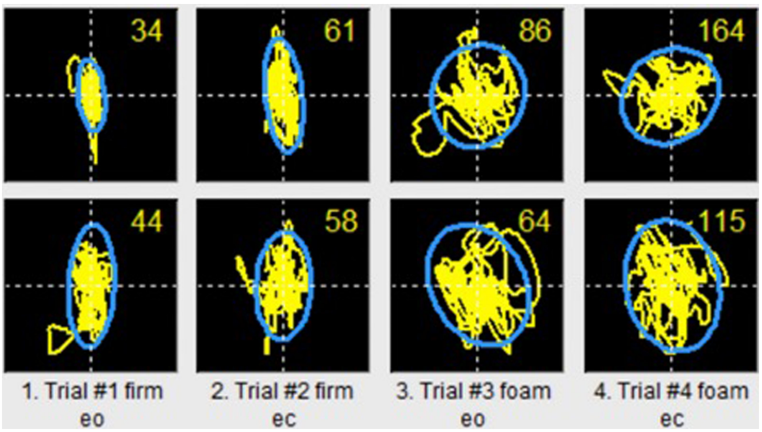

Fig. 3. Total COP path length (yellow line) and 95% ellipse area (blue line) for baseline (top) and post-treatment (bottom).
The COP path length is reported in cm. A smaller total COP path length is equated to better postural control. EO: eyes open; EC: eyes closed. Note the axes of the stabilogram plots are not standardized, thus not comparable by observation.

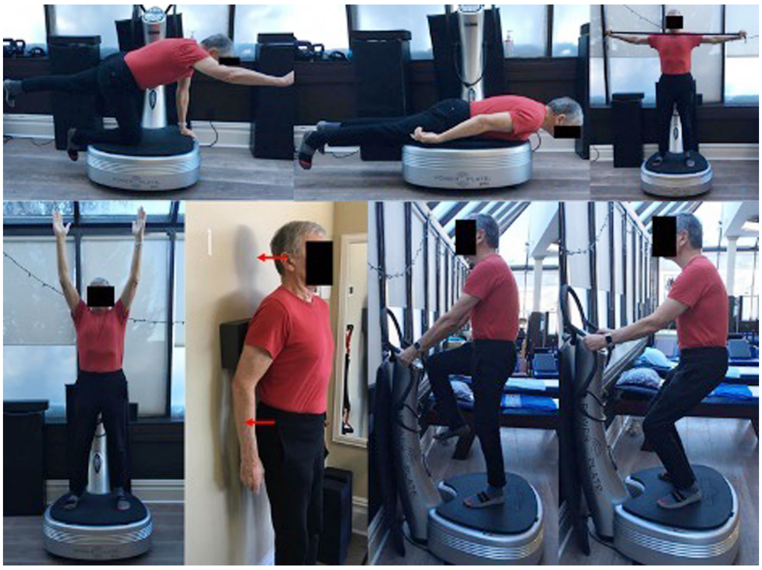

Fig. 4. Corrective exercises.

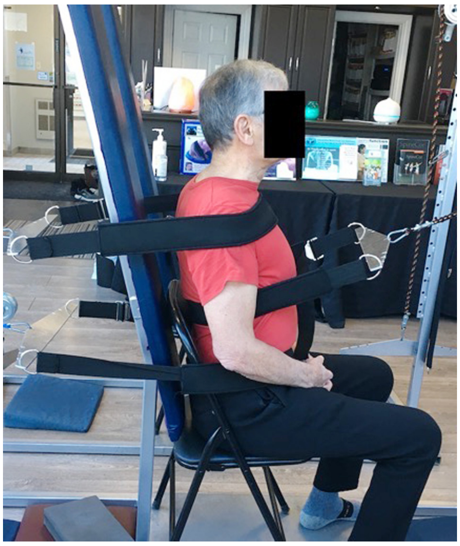

Fig. 5. Spinal traction set-up.
In a seated position, to maintain stability and comfort, the patient is secured in position with the lap belt. The thoracolumbar belt is placed approximately at the T12 vertebral level pulling forward and slightly superior. A shoulder belt is pulling the upper back rearward to create torque. The patient remains relaxed in position for 10–20 minutes per session.

in-clinic. Paraspinal stimulation using a dual-pronged attachment via a hand-held percussion instrument was also performed throughout the cervical, thoracic and thoracolumbar areas to mechanically massage the tight muscles.

RESULTS

An assessment approximately four months after initial presentation (Feb. 3, 2023) demonstrated a 78.6 mm reduction in positive sagittal balance (C7–S1: −5.8 mm vs. 72.8 mm) and a 10.1° reduction in the thoracolumbar kyphosis (Cobb T10–L2: 19° vs. 29.1°) (Fig. 1). There was also an improved postural control in the more difficult trials involving foam with EO/EC (Trials 3,4; Table 1; Fig. 3). The vestibular condition total COP path length now approached the 50th percentile for elderly 60+ years[38)] (115 cm vs. 165 cm). All COP metrics improved (smaller values) for the foam trials (Table 1; Fig. 3). The patient reported improvements on subjective outcomes, including better sleep (1/5 vs. 3/5, ODI ‘sleeping’ section), less pain (1/5 vs. 3/5, ODI 'changing degree of pain' section), improved walking ability (i.e. "less irritating", 1/5 vs. 2/5, ODI 'walking' section), and that the muscles in the low back did not ache any longer (i.e. NPRS 0/10 vs. 5/10). There was also a reduction on the ODI to the level of minimal-moderate disability (22% vs. 38%). The low back and hips were still stiff coming out of bed and after maintaining a static position for too long, however, this no longer caused LBP. Visual inspection of gait revealed it was improved as the patient remained in a more vertical position throughout the gait cycle. Palpation of the spinal muscles continued to show paravertebral hypertonicity throughout the entire thoraco-lumbar spine and neck. Visual range of motion assessment showed a marked decrease in flexibility in all directions for the neck and back with improved movements observed throughout the low back. Lower extremity muscle testing continued to show reduced hip extension strength as well as toe and heel walking endurance. Hip flexibility testing showed limited range in all directions bilaterally. The patient has chosen to remain under treatment seeking to maintain the achieved improvements. The patient gave verbal and written consent for the publication of these results including all X-rays/pictures. There were no adverse events. The patient described the treatment challenging at first, but over time became more tolerable; the improvement in pain/results also became a motivator to continue with the treatments.

DISCUSSION

This case demonstrates the significant improvement in postural control (standing balance) as quantified by the mCTSIB and the reduction of excessive forward sagittal balance (SVA) and thoracolumbar kyphosis as demonstrated on post-treatment X-rays after 4-months of a comprehensive CBP postural rehabilitation program. The patient also experienced improvement in sleep, pain, disability, and mobility.

Classically, ASD has four spine deformity components and patients 18 years of age and older having any one of these four components are classified as having this condition. These four spine deformities include: 1) thoracic kyphosis at any vertebral levels ≥60°, 2) anterior displacement of the C7–S1 SVA >50 mm, 3) decreased distal lumbar lordosis and pelvic tilt, and 4) a scoliotic curvature >20°[3]. The patient herein has 2/4 components of ASD (thoracic hyperkyphosis and increased SVA) with a primary anterior displaced sagittal balance. Like the current patient, many ASD patients demonstrate excessive forward lean of the body (i.e. SVA) which forces these patients to employ compensatory mechanisms to maintain the CM over the femur heads (in order to maintain the CM within the base of support)[44]. An anterior shift of the CM of the trunk requires significant compensatory and uneconomical efforts to compensate[45, 46]; thus, a net anterior shift of the CM indicates a failure of compensation or decompensated anterior shift[44]. Indeed, healthy patients adopting a stooped posture have been shown to demonstrate postural control impairments[47].

Patients with increased SVA show greater COP metrics indicative of postural control impairment[48–50]. Ito et al. demonstrated that patients with an SVA >40 mm showed a greater RMS displacement in the EC condition in comparison to control participants; however, the control was young and healthy and not age-matched[48]. Godzik et al. determined thoracic hyperkyphosis deformity positively correlated with ML sway displacement in EO and EC conditions as well as total sway area in the EC condition in comparison with age-matched controls[49]. Also, Yagi et al. showed those with SVA >50 mm and/or scoliosis >20° displayed greater sway area, y-axis distance and left-to-right differences in ground reaction forces[50]. There have also been studies showing ASD patients having thoracic hyperkyphosis show lower (worse) sensory organization test (SOT) scores as compared to age-matched controls[51, 52]. Thus, there is evidence that patients with ASD display postural control impairment. This was also apparent in the current case by comparing the total COP sway path to the BTrackS normative adult values[36, 37] and elderly percentiles[38].

When inspecting the improvement in postural control post-treatment, it is apparent that the largest gains (and largest deficiencies pre-treatment) were shown for trial 4, the vestibular condition. The vestibular system creates a gravitoinertial frame of reference for postural control by providing the CNS with position and movement information about the head with respect to gravity and inertial forces[53]. The vestibular system is thought to have a higher threshold[54] for recruitment and therefore, is indicative of contributing the dominant sensory input in the last trial in the mCTSIB (where there is no vision and proprioception is challenged by standing on the foam). Others have demonstrated deficiencies in postural control in conditions which predominantly isolate the vestibular system[51, 52] pointing to vestibular impairment in patients with ASD.

Sim et al.[55] determined that patients with adolescent idiopathic scoliosis (AIS) demonstrated increased energy rates, as determined by discrete wavelet transformation of the COP, for increasing severity of scoliosis spine magnitudes. In other words, larger spinal deformity demonstrated high power in sway. Importantly, the highest energy content in the COP power spectrum appeared in the range associated with vestibular input (rather than visual and somatosensory inputs)[55]. Why impairment of the vestibular component in postural control is prevalent among ASD patients is not known. It has, however, been suggested that these patients maximally exert compensatory muscles and 'postural reserves' in attempt to maintain postural steadiness[49] as those with thoracic hyperkyphosis, for example, may have greater fatigue in paravertebral spinal muscles[56]. More research is necessary to elucidate the mechanisms responsible.

Improved sagittal spine and posture alignment of the cervical-thoracic region in the current case is likely to have been significantly responsible for the improved balance measures herein. In a recent case control investigation, Moustafa et al.[57] identified a linear correlation between the magnitude of forward head posture and sensori-motor control measures including postural stability as measured using the Biodex Balance System. Similarly, in three recent randomized trials[58–60], improved sensori-motor control measures were found to result from CBP technique applications that improved forward head posture and cervical lordosis[58, 59] and to result from reduction of thoracic hyperkyphosis[60]. Importantly, one of the cervical spine trials[59] assessed and treated elderly patients exclusively and found improved performance on the Berg Balance Scale as a result of improved cervical sagittal plane posture to within normal limits. Although the improved postural alignment likely contributed to the improved postural control, an important contribution may have also resulted from the use of WBV[43]. The use of WBV exercise training has been shown to improve static balance in the older population in as little as 8-weeks[61, 62]. In fact, WBV exercise has been shown to be a safe and effective treatment intervention and has been recommended to compliment other exercise interventions aimed at improving mobility in the elderly[61, 62]. Rigoni et al. suggest that WBV presents a challenge to the body that initially overwhelms the sensorimotor regulation of balance, but after a brief accommodation period, a cortical shift towards supraspinal control occurs that recalibrates muscle recruitment leading to improved postural control[63]. In essence, WBV training modulates muscle activation to better regulate the postural control system by the formation of new muscle synergies, indicating a recalibration of the sensorimotor set[63]. Regardless of which of the two methods (posture improvement or use of WBV) improved the patient more, it is apparent that the multi-modal treatment regimen used herein, resulted in improved postural control.

It must be noted that clinically, there has been a reliance on radiographic analysis of patients with ASD[13]. This will undoubtedly continue as this is the precise method of diagnosis, however, there is a need to incorporate dynamic and functional testing in the assessment and treatment of ASD patients. This case represents evidence that a practical and functional assessment can be easily incorporated into daily clinical practice, and it also represents an example that spine rehabilitation programs can improve balance performance. Importantly, the functional balance improvement would not have been recognized and herein documented without incorporating the mCTSIB testing protocol. Thus, the inclusion of the mCTSIB with a portable force plate as in the present case may add an extra piece of clinical data that may be used to screen and document a functional measure not typically used in clinical practice.

Limitations to this case includes a lack of follow-up. This report is for a single patient and therefore, no generalizations can be made for an entire patient cohort; however, the results of recent trials offer encouragement of the effects of posture correction and PowerPlate balance training on sensorimotor control in ASD populations[59, 60]. In the future, a study designed to explore potential differences between PowerPlate and CBP posture correction methods could elucidate whether the improved postural control was attributable to the PowerPlate exercises, the improved posture, or a combination of both. It should be mentioned that there is the possibility that the balance improved regardless of treatments received, however, we doubt this is likely since older individuals typically have deterioration of postural control over time[64]. Further, although many recommend postural stability trial durations longer than 20 seconds (e.g. 90 seconds) and to average more than a single trial (i.e. 3–5 trials)[65], it may not be feasible for some older patients with ASD to perform multiple, longer trial durations; thus, shorter trial durations such as 20s used in this case may represent a viable approach for posturography testing that has maximal clinical utility[66].

In considering the overall pre-post treatment results of the mCTSIB, in condition 1 (EO-firm), it appears the patient performed 10 cm worse for the COP total path length (44 cm vs. 34 cm). It should be noted that the minimal detectable change (MDC) for the COP total path length has been calculated to be approximately 10 cm[67], thus, this change does not appear to be significant. Finally, it is noted that the balance test was performed in an open room with uncontrolled acoustic conditions, however, it has been determined that this may not affect posturography measures to any significant degree[68]. Future studies should include multiple patients (series) and also the presentation of different spinal deformity conditions.

This case demonstrates the significant improvement in postural control as quantified by the mCTSIB following whole body vibration exercises and spinal rehabilitation resulting in the reduction of increased SVA and thoracolumbar kyphosis as demonstrated on post-treatment x-rays. These results are consistent with recent trials offering encouragement of the effects of posture correction on sensorimotor control in adult spinal deformity populations.

Conflicts of interest

P.A.O. is a paid consultant for CBP NonProfit, Inc. D.E.H. teaches continuing education conferences to health care providers, is the CEO of Chiropractic BioPhysics, teaches rehabilitation methods, and distributes products for patient rehabilitation to physicians in the USA. W.H.G. and G.M. have no competing interests to declare.

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