A Preliminary Study to Evaluate Postural Improvement in Subjects With Scoliosis: Active Therapeutic Movement Version 2 Device and Home Exercises Using the Mulligan's Mobilization-With-Movement Concept

Clare Lewis, DPT, PsyD,[a] Rafael Diaz, PhD,[b] Geoff Lopez, MPT,[c] Nicholas Marki, MPT,[c] and Ben Olivio, MPT[c]

Abstract

Objective: The purpose of this preliminary study was to determine if the use of Active Therapeutic Movement Version 2 (ATM2) device and home exercises using the Mulligan's mobilization-with-movement concept by subjects with scoliosis would result in postural improvement and to document any changes in trunk range of motion and quality of life.
Methods: Forty-three subjects between the ages of 12 to 75 years were recruited for the study. Each subject underwent a low back evaluation along with specific measurements for their scoliosis. Subjects participated in a 4-week intervention, 2 times a week consisting of treatment utilizing the ATM2 and were also given a home exercise program to mimic the specific movement(s) they performed on the ATM2. Photographic assessment of posture was taken before and after the intervention. Subjects were surveyed during the initial assessment and again at the final intervention using the following outcome measures: Fear Avoidance Belief Questionnaire, Short-Form Health Survey-36, Oswestry Disability Index, and a Numeric Pain Rating Scale.
Results: Results were significant for most of the variables measured. Subjects gained improvement in spinal ranges of motion for all directions except for flexion and extension (most subjects had reference range of flexion and extension at the beginning of the study). Most subjects had improved pelvic alignment after the intervention. Before and after photographs demonstrated improved posture. Subjective measurements of pain, disability, and quality of life improved.
Conclusions: Results of this preliminary study showed improvement for selected variables. The use of ATM2 and home exercises using the Mulligan's mobilization-with-movement concept by subjects with scoliosis appears to be a potentially viable conservative treatment alternative to address various findings associated with scoliosis, including posture improvement. (J Manipulative Physiol Ther 2014;37:502-509)
Key Indexing Terms: *Scoliosis; Body Image; Posture; Therapeutics*

Idiopathic scoliosis is a disputed subject in orthopedic surgery because of its several varieties, unknown cause, and unpredictable course.[1] *Scoliosis* is defined as a lateral deviation of the spine, having a minimum Cobb angle of 10° with concordant vertebral rotation.[2,3] Adolescent idiopathic scoliosis, the commonest variety, has been shown to have a greater frequency in girls.[1] The prevalence of scoliosis in the adolescent population has an incidence of 2% to 4%. Of those diagnosed, only 10% progress and require medical intervention. Unfortunately, nonsurgical treatment interventions including medications, exercise, physical therapy, and chiropractic treatments have not yielded significant benefits in health quality-of-life measures.[4-7]

The effects of scoliosis are 2-fold: when advanced, the deformity can be disfiguring, which may cause psychosocial disability,[8] and second, the thoracic distortion can cause mechanical pulmonary restriction resulting in symptoms if the curve is severe enough.[6] Mild-to-moderate scoliosis (defined as Cobb angle <40° at the end of growth) usually has a benign prognosis in adult life.[9] Although there are reports of increased incidence and/or severity of back pain in adult life, this cannot be reliably predicted or prevented.[10]

[a] Professor, Sacramento State University, Physical Therapy Department, Sacramento State University, Sacramento, CA.
[b] Associate Professor, Sacramento State University, Mathematics and Statistics, Sacramento State University, Sacramento, CA.
[c] MPT, Student Sacramento State University, Physical Therapy, Sacramento State University, Sacramento, CA.
Submit requests for reprints to: Clare Lewis, PT, DPT, PsyD, MS, MPH, 3127 Spinning Rod Way, Sacramento, CA 95833. (e-mail: *lewisc@csus.edu*).
Paper submitted October 23, 2012; in revised form July 14, 2014; accepted July 14, 2014.
0161-4754

http://dx.doi.org/10.1016/j.jmpt.2014.07.005

Deformities present at skeletal maturity persist for life and can continue to progress over time. The mechanism for progression of scoliosis in adults is not well defined but presumably involves remodeling of tissues by "wear-and-tear" effects of continuous loading because growth potential is absent. Adult curvatures repeatedly have been found to progress in proportion to curvature magnitude. This observation is consistent with the possibility that, in adults as well as in children, progression results from biomechanical loading imbalance, and therefore, increased loading fosters increased progression.[11] In one study of 187 patients followed up for more than 15 years after skeletal maturity, 20° to 29° curvatures progressed 10°, on average; 30° to 39° degree curvatures progressed 12°; 40° to 49° curvatures progressed 15°; and 50° to 59° curvatures progressed 20 degrees.[12] Variation in progression among adult patients with similar curvatures may be predicted to result from different muscle activation strategies that alter the loading imbalance. Curvatures of less than 20° are less likely to progress than more severe curves, perhaps because they produce mechanical loads below the threshold required to induce cellular changes leading to degenerative changes in spinal elements. However, even mild curves that remain stable become increasingly rigid with age presumably, from secondary effects of altered mechanical loading.[11,13]

A body of research has demonstrated that, whatever the initial trigger that induces a spinal curvature, asymmetric loading of the spinal axis produces biomechanical forces that can account for most if not all progression of the spinal deformity.[13] Structural damage to bone and disc can occur very early in the development of even minor curves.[14]

With a mild spinal deformity (barely visible when the patient is undressed), in a postpubertal child, the curve is unlikely to progress and does not require any treatment.[1] If the deformity is mild but it is believed that the curve will progress or deteriorate, then there is dispute among experts on what the final curve status might be.[15,16] An increase of 5° or more in the Cobb angle is taken as noteworthy progression.[2] Where there is severe deformity that is unacceptable to the patient, causing distress and psychologic damage, surgical correction is recommended; only the timing and methodology may give rise to discussion. Evidence to support nonoperative treatment has not been demonstrated in the literature and has not reduced the incidence of surgical intervention.[1]

Traditional treatment for idiopathic scoliosis has consisted of different procedures including casting, bracing, electrical stimulation, exercises, and surgery.[17-19] Some of these treatments have fallen out of favor due to lack of efficacy, and others have evolved as technology and medical advances have offered better clinical outcomes.[20] Although advances in surgical methods have been noteworthy, (eg, minimally invasive surgery, which is best suited for thoracic curves,[21]) many of the physical and emotional problems associated with living with scoliosis have not been well addressed by conventional therapies. Until the physical and emotional problems associated with living with scoliosis are resolved, conclusions on management must be provisional.

Fig 1. *The device used in this study.*

The Active Therapeutic Movement Version 2 (ATM2) (Back Project Corporation, Sunnyvale, CA) (Fig 1) is a device that was designed originally to treat spinal pain and has been used for neck, pelvis, hip, knee, and shoulder conditions. The manufacturers theorize that the machine trains the patient, through repetition and repositioning, to move ways that are pain free and to activate and strengthen core stabilization muscles. In a case study,[22] it was reported that the ATM2 showed some benefit in kyphoscoliosis posture in a patient with scoliosis. It was theorized that the mechanism responsible for the changes may have been from stabilizing the pelvis during the treatments, which could have allowed more isolated spinal motion. However, without larger studies with more patients, the conclusions could not be conclusive.

Therefore, the purpose of this preliminary study was to determine if the use of ATM2 and home exercises using the Mulligan's mobilization-with-movement concept by subjects with scoliosis would result in postural improvement and to document any changes in trunk range of motion and quality of life.

Methods

The study utilized a nonrandomized prospective intervention for individuals with mild-to-moderate scoliosis (<40° that did not require surgery). The Sacramento State Committee for Approval of Human Subjects approved the study, and informed written consent to participate in the study was obtained from all subjects.

Participants

Forty-three subjects (37 women, 6 men; mean age 43.5 years; range 14-63 years) were recruited by flyers posted on the California State University, Sacramento campus, by presentations given to the Sacramento scoliosis support group and through presentations to local yoga classes conducted for people with scoliosis. Subjects were included in the study if they met the following criteria: were between the ages of 12 to 75 years, were determined to have mild-to-moderate scoliosis curvature upon examination, and were diagnosed by their physician to have mild-to-moderate scoliosis. Subjects were excluded from the study if they had previously undergone operative treatment for scoliosis, were pregnant, had any serious medical comorbidities, were claustrophobic, or had severe back pain that required medication.

Outcome Measures

All subjects received a low back examination at the first visit. In addition to his or her background history, each subject was asked about the onset of his or her scoliosis. All subjects in our sample had primary juvenile onset scoliosis. The objective examination focused on the subjects' postural faults, documentation of the direction of frontal plane curvature, and spinal range of motion. Physical therapy student investigators participated in data collection. These students demonstrated measurement competency in techniques in measurement procedures, including the use of tape measures, goniometers, bubble inclinometers, and visual postural examination. The physical examination included taking height measurement, weight, and visually assessing subjects' posture from anterior, posterior, and lateral views against a posture grid. Spinal range of motion and subjective pain response were measured at the initial evaluation, before and after each intervention and after the last intervention session.

Trunk rotation was measured using a goniometer, with the starting position for trunk rotation in sitting to stabilize the pelvis via weight bearing. Thoracolumbar extension and flexion were measured while standing by using 2 inclinometers (see Fig 2). The inclinometer was marked with a piece of tape on which a line was drawn to ensure consistent placement of inclinometer to the spinous process each time. One inclinometer was placed on L1, and the other was placed on S1 after palpating and marking the spinous process of each level. Side bending was recorded by measuring the distance from the longest fingertip to floor with a tape measure. A pelvimeter (see Figs 3 and 4) was used to assess any asymmetry of the pelvis, which is sometimes seen with patients who have scoliosis and may be a possible cause of scoliosis.[23] Asymmetry of the pelvis can be due to such things as a leg-length discrepancy, a hemipelvis, or a rotated innominate to name a few.[24] The pelvimeter was adjusted, so each of the sagittal plane rods was placed on top of the subjects iliac crests with equal distance between the liquid bubble leveler and each innominate. The sagittal plane rods were then gently squeezed medially to obtain standard placement and consistent pelvis level placement. The measurement was read by observing the liquid bubble on the pelvimeter and documenting any deviation from 0° (which indicates that the pelvis is not level). If the bubble was not level, the measurement recorded was in reference to the lower side innominate.

Fig 2. *Measuring backward bending with 2 bubble inclinometers.*

Presence of rib hump was assessed using the Adam's Bend test. Photographs were taken of the subjects in an anterior, a posterior, and a lateral view for comparison later and to help assess bodily characteristics. Photos were also taken to document subjects' curvature, which was first palpated and marked using skin markers. Subjects were surveyed during the initial assessment and again at the final intervention using the following outcome measures: Fear Avoidance Belief Questionnaire (FABQ), Short-Form Health Survey-36, Oswestry Disability Index, and a Numeric Pain Rating Scale (NPRS).

Intervention

Subjects participated in a 4-week intervention. Each subject came 2 times per week to be consistent with a

Fig 3. *The pelvimeter.*

Fig 4. *Using the pelvimeter to take a measurement.*

typical clinical schedule frequency. Active Therapeutic Movements were done to assist in mild mobilization with movement (based on the Mulligan's mobilization-with-movement concept)[25] for the spine on the ATM2, a standing treatment table with straps that encircle the subjects pelvis and are adjusted by using ratchets that move the pelvis into anterior or posterior rotation according to subjects' subjective preference.

Subjects were set-up so that they could actively move their trunk while stabilized in a position resulting in pain-free range of motion against a resistance band into the direction that reversed their curve (side bending) for 3 sets of 10 repetitions (Fig 5). Most subjects participated in an additional movement to address limitations in other directions (rotation and extension). Subjects completed 1 set of 10 repetitions on the first visit, 2 sets on the second visit, and 3 sets on the third visit and those thereafter until completion of 8 visits. Using a 1-second verbal count standardized timing of repetitions. Subjects were assigned home exercises to address the limitations in range of motion and curvature found during the initial evaluation. This home exercise program was done by having the subject sitting in a stable chair to stabilize the pelvis, and subjects were instructed to move in same the direction of the resisted motion used for intervention on the ATM2 at the frequency of 10 repetitions 2 times a day.

Results

Range of Motion

Range of motion (see Table 1) showed a significant increase in right-side bending with an average decrease of 1.97 cm ($P < .001$) (95% bootstrap confidence interval [CI] is in agreement with the t test). Left-side bending was significant with an average decrease of 1.3 cm ($P < .05$) when the outlier (not in favor of the alternative hypothesis of an increase in left-side bending after the treatment) was removed; however, the presence of the outlier violates the assumptions of the t test, and therefore, the more reliable bootstrap 95% CI shows that without a reason to remove the outlier, the difference between pretreatment and posttreatment in left-side bending is not significant at the 0.05 level (this CI contains the number zero). Right rotation showed significant average increase of 5.3° ($P < .01$) when the outlier (in favor of the alternative hypothesis of a positive difference between posttreatment and pretreatment) is removed. This a conservative significant result because without any reason to remove this outlier, the mean increase in right rotation goes up to 6.2°, and the bootstrap 95% CI estimates higher values in the estimation of this mean. The presence of other outliers in the data for left rotation violates the assumptions of the t test, so a bootstrap CI was used for to analyze this variable. This CI shows that there was a significant increase in the left-rotation angle (mean, 4.7°), and it also shows by not including 0 that this difference is significant at least at the 0.05 level.

Pelvimeter

Pelvimeter results (see Table 2) could not be analyzed with the t test due to 2 outliers; however, the bootstrap CI shows a positive effect for this variable after treatment.

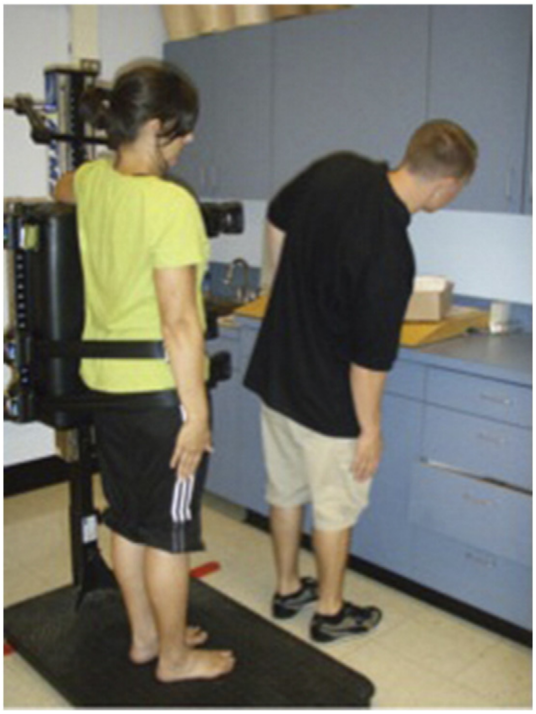

Fig 5. *Subject performing right-side bending for right thoracic curve.*

Numeric Pain Rating Scale, Oswestry, and FABQ

Numeric pain rating scale showed a significant average decrease of 1.5 U ($P < .001$) when the outlier (in favor of hypothesis) is removed (see Table 3). Oswestry Low Back Pain Disability questionnaire (see Table 3) showed a significant average decrease of 3.7 U ($P < .05$) (no *t* test due to the presence of outliers). Trunk flexion, trunk extension, and FABQ were not significant, although a $P = .07$ indicates that there may be a tendency in trunk flexion measurements to increase after treatment (see Tables 1 and 3).

Short-Form Health Survey-36 Analysis

Physical functioning domain showed a significant average increase of 6.4 U ($P < .05$) (no *t* test due to outliers). Vitality showed a significant average increase of 9.6 U ($P < .001$); a bootstrap 95% CI shows agreement with that of the *t* test. Mental health showed a significant average increase of 6.13 U ($P < .05$) (no *t* test due to outliers). Social function showed a significant average increase of 8.9 U ($P < .05$) (no *t* test due to outliers). Bodily pain showed a significant mean change of 14.4 U ($P < .001$); the bootstrap 95% CI is in agreement with that of the *t* test. General health showed a significant average increase of 5.3 U ($P < .01$) without an outlier (in favor of the alternative hypothesis of a positive change from pretreatment to posttreatment). This significant mean change is a conservative estimate because even when this "favorable" outlier is included in the analysis, the mean change goes up to 6.8 U, and the bootstrap 95% CI predicts higher estimates for this mean change. Role limitations due to physical and role limitations due to emotional were not significant (see Table 4 for Short-Form Health Survey-36 results).

Discussion

Many conservative treatments have been used over the years for the treatment of mild-to-moderate scoliosis, often with limited effectiveness. This study was undertaken to determine the efficacy of a conservative intervention for the treatment of scoliosis. The ATM2 was originally conceived as a means to assist the practitioner with accomplishing Mulligan's mobilization-with-movement treatment because manually treating patients with this technique was physically demanding for the practitioner. Use of this device has evolved over time to include treatment of conditions beyond low back pain with the discovery, such as postural corrections resulting in unintended positive side effects.[22]

The results for the current study showed that subjects gained improvement in spinal ranges of motion for all directions except for flexion and extension. The likely reason that results did not show significant difference for these 2 directions of movement is that most subjects had reference range of flexion and extension at the beginning of the study. For example, most subjects could touch their long finger to the floor at the beginning of the study, which meant that there was no measurement improvement possible. Also of note, all subjects with a thoracic curve were right thoracic (which is the most common type of thoracic curve), and subjects showed more improvement with right rotation, which is consistent with positive improvement.

Results from the pelvimeter measurement (ie, determines pelvic alignment in the frontal plane) showed that most subjects went from more pelvic obliquity to less after the intervention. Before and after photographs demonstrated the change in the subjects' posture (see Figs 6 and 7).

Subjective measurements of pain, disability, and quality of life improved for all testing instruments used except for the FABQ. The FABQ may not have been as accurate for our population, as it has been validated for individuals who work, and most of our subjects were either retired or college students. In addition, most reliability and validation studies for the FABQ have been undertaken in chronic low back pain populations, and pain was not really a significant variable for most of our subjects.[26] Anecdotally, many of our subjects expressed satisfaction with the intervention and felt that the results were meaningful enough that family and friends noticed the positive difference in their posture.

Table 1. *Trunk Range of Motion Prechange/Postchange in Range of Motion*

	Mean of the Differences (95% CI)	Mean of the Difference (Bootstrap 95% CI)	*P*
Trunk flexion	2° (−0.3 to 5.1°) [a]	2° (−0.5 to 4.97) [b]	.08
Trunk extension	N/A	5 (−7.3 to 1.1) [b]	>.05
Right-side bending	**2 cm (0.9-3.1 cm)**	**2 (0.97-2.96)**	**.001** [c]
Left-side bending	**1 in (0.09-2.2 cm)** [a]	1 (−0.4 to 2.4) [b]	**.036** [c]
Right rotation	**5° (1.4-9.3)** [a]	**6 (2.2-10.4)** [b]	**.010** [c]
Left rotation	N/A	**5° (1.2-8.1)**	**<.05**

CI, confidence interval; *N/A*, not available.
Bolded, significant.
[a] Without outlier(s).
[b] With outlier(s).
[c] *P* values for paired *t* tests.

Table 2. *Pelvimeter Prechanges/Postchanges in Pelvis Obliquity*

Pelvimeter	Mean of the Differences (95% CI)	Mean of the Difference (Bootstrap 95% CI)	*P*
	N/A	**0.4 (0.01-0.7)** [a]	**<.05**

CI, confidence interval; *N/A*, not available.
Bolded, significant.
[a] *P* values for paired *t* tests with outlier(s).

Table 3. *Subjective Questionnaires Preintervention/Postintervention*

	Average Change	Mean of the Difference (Bootstrap 95% CI)	*P*
NPRS	2 [a]	(0.7) [a]; (0.95, 2.4) [b]	<.001
OSW	2 [a]	**4 (1.4-6.2)**	**<.05**
FABQ	N/A	3 (−0.8 to 7.6)	>.05

CI, confidence interval; *FABQ*, Fear Avoidance Belief Questionnaire; *N/A*, not available; *NPRS*, numeric pain rating scale; *OSW*, Oswestry Low Back Pain Disability.
Bolded, significant.
P values for paired *t* tests.
[a] Without outlier(s).
[b] With outlier(s); OSW, Oswestry Low Back Pain Disability.

Limitations

The criterion standard for determining the degree of spinal curvature for patients with scoliosis is by utilization of radiographs, which can determine the exact amount of spinal curve. Our study was limited in that we were unable to use radiographs to measure the spinal curvature of our subjects. Other limitations are as follows. We only had a small sample of participants who are not fully representative of the general population; therefore, generalizability of our findings is limited. Larger studies will be needed to determine effects on other groups of people. There were variants within the results, with outliers. Larger numbers of subjects might assist with this issue in future studies. As well, this was a short-term study. It is unknown if the findings would have long-term or lasting effects.

Table 4. *Short-Form Health Survey-36 Analysis Preintervention/Postintervention*

Domain	Mean of Differences (95% CI) [a]	Mean of Differences (Bootstrap 95% CI)	*P*
Physical functioning	N/A	**6 (2.6-10.9)**	**<.05**
Role, physical	N/A	10 (0.0-21.4)	>.05
Role, emotional	N/A	7 (-1.5-16.2)	>.05
Vitality	**10 (4.8-14.4)**	**(4.9-14.2)**	**.000** [c]
Mental health	N/A	**6 (2.3-10.1)**	**<.05**
Social function	N/A	**9 (3.9-13.8)**	**<.05**
Bodily pain	**13 (6.7-20.2)**	**(6.9-19.9)**	**.000** [c]
General health	**5 (2.1-8.6)** [a]	**7 (3.1-11.5)** [b]	**.002** [c]

CI, confidence interval; *N/A*, not available.
Bolded, significant.
[a] Found by paired *t* test without outlier(s).
[b] With outlier(s), significant if 95% does not contain 0.
[c] *P* values for paired *t* tests.

Conclusion

Results of this preliminary study showed improvement for selected outcome measures. The use of ATM2 and home exercises using the Mulligan's mobilization-with-movement concept by subjects with scoliosis appears to be a potentially viable conservative treatment alternative to address various findings associated with scoliosis, including posture improvement.

Practical Applications

- Results from this study demonstrated improvement in objective and subjective outcomes for subjects with mild-to moderate-scoliosis.
- Subjects in the study had improved range of motion, improved posture, and improved sense of well-being.

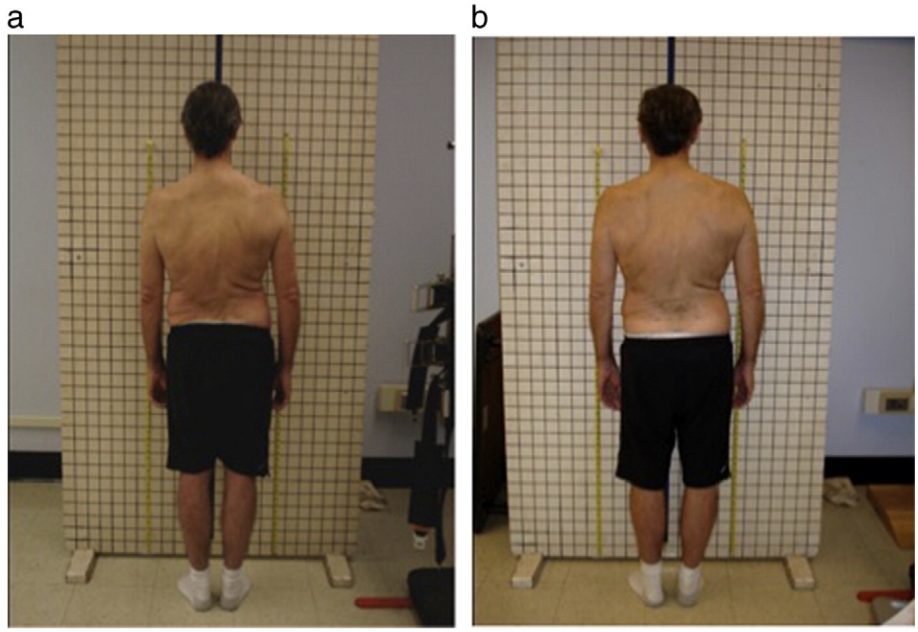

Fig. 6. *Subject before (A) and after (B) intervention.*

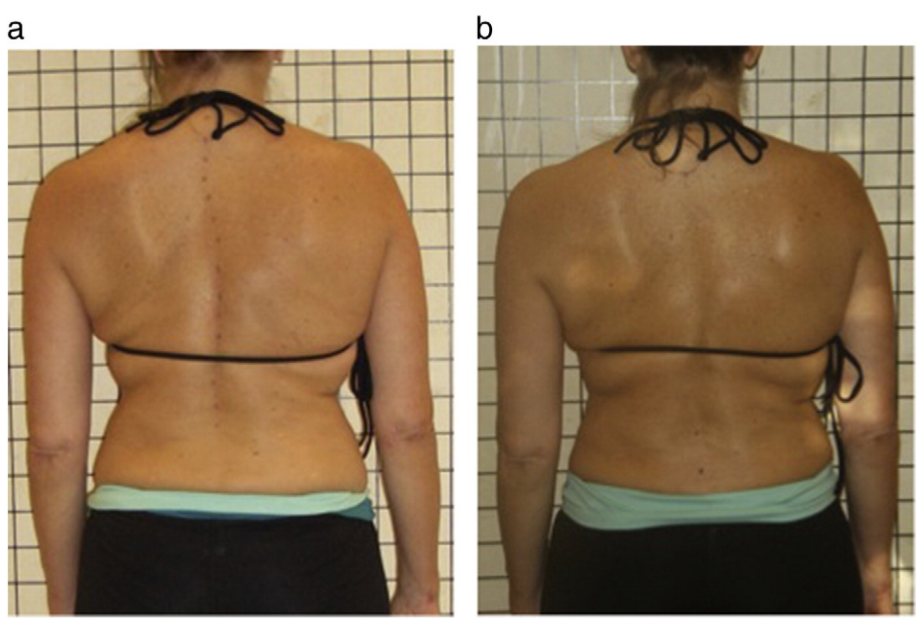

Fig. 7. *Subject before (A) and after (B) intervention.*

Funding Sources and Potential Conflicts of Interest

No funding sources or conflicts of interest were reported for this study.

Contributorship

Concept development (provided idea for the research): C.L.

Design (planned the methods to generate the results): C.L.

Supervision (provided oversight, responsible for organization and implementation, and writing of the manuscript): C.L.

Data collection/processing (responsible for experiments, patient management, organization, or reporting data): C.L., B.O., G.L., and N.M.

Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): R.E., B.O., G.L., and N.M.

Literature search (performed the literature search): C.L.

Writing (responsible for writing a substantive part of the manuscript): C.L.

Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): C.L. and R.E.

References

1. Goldberg C, Moore P, Fogarty E, Dowling F. Scoliosis: a review. Pediatr Surg Int 2008;24:129-44.
2. Bunnell W. The natural history of idiopathic scoliosis before skeletal maturity. Spine 1986;11:773-6.
3. Stokes I. Three-dimensional terminology of spinal deformity. A report presented to the Scoliosis Research Society by the Scoliosis Research Society Working Group on 3-D terminology of spinal deformity. Spine 1994;19:236-48.
4. James J. Idiopathic scoliosis: the prognosis, diagnosis and operative indications related to curve patterns and the age of onset. J Bone Joint Surg 1954;36:36-49.
5. Goldberg C, Fogarty E, Moore D, Dowling F. Left thoracic curve patterns and their association with disease. Spine 1999; 24:1228-33.
6. Branthwaite M. Cardiorespiratory consequences of unfused idiopathic scoliosis. Br J Dis Chest 1986;80:360-9.
7. Goldberg C, Moore D, Fogarty E, Dowling F. Handedness and spinal deformity. In: Uyttendaele D, Dangerfield P, editors. Research into spinal deformities, vol 5. Amsterdam: IOS Press; 2006. p. 442-8.
8. Nachemson A. A long-term follow-up study of non-treated scoliosis. Acta Orthop Scand 1968;39:466-76.
9. Weinstein S, Dolan L, Spratt K, Peterson K, Spoonamore M, Ponseti I. Health and function of patients with untreated idiopathic scoliosis. A 50-year natural history. JAMA 2003; 289:559-67.
10. Danielsson A, Wiklund I, Pehrsson K, Nachemson A. Health-related quality of life in patients with adolescent idiopathic scoliosis: a matched follow-up at least 20 years after treatment with brace or surgery. Eur Spine J 2001;10: 278-88.
11. Hawes M, O'Brien J. The transformation of spinal curvature into spinal deformity: pathological processes and implications for treatment. Scoliosis 2006;1:3.
12. Ascani E, Bartolozzi P, Logroscino C, et al. Natural history of untreated IS after skeletal maturity. Spine 1986;11:784-9.
13. Korovessis P, Piperos G, Sidiropoulos P, Dimas A. Adult idiopathic lumbar scoliosis: a formula for prediction of progression and review of the literature. Spine 1994;19:1926-32.
14. Mehta MH. Pain provoked scoliosis. Clin Orthop Relat Res 1978;135:58-65.
15. Goldberg C, Dowling F, Regan B, Blake N. A retrospective study of Cotrel dynamic spinal traction in the conservative management of scoliosis. Ir Med J 1981;74:363-5.
16. Goldberg C, Dowling F, Fogarty E, Regan B, Blake N. Electro-spinal stimulation in children with adolescent and juvenile scoliosis. Spine 1988;13:482-4.
17. Dickson R. Conservative treatment for idiopathic scoliosis. J Bone Joint Surg (Br) 1985;67:177-81.
18. Hawes M. The use of exercises in the treatment of scoliosis: an evidence-based critical review of the literature. Pediatr Rehabil 2003;6:171-82.
19. Maruyama T, Kitagawa T, Takeshita T, Mochizuki K, Nakamura K. Conservative treatment for adolescent idiopathic scoliosis: can it reduce the incidence of surgical treatment? Pediatr Rehabil 2003;6:215-9.
20. Howard A, Donaldson S, Hedden D, Stephens D, Alman B, Wright J. Improvement in quality of life following surgery for adolescent idiopathic scoliosis. Spine 2007;32:2715-8.
21. Guille J, D'Andrea L, Betz R. Fusionless treatment of scoliosis. Orthop Clin North Am 2007;38:541-5.
22. Lewis C, Erhard R, Drysdale G. Kyphoscoliosis improvement while treating a patient for adhesive capsulitis using the Active Therapeutic Movement Version 2. J Manipulative Physiol Ther 2008;31:715-22.
23. Tsirikos A. Development and treatment of spinal deformity in patients with cerebral palsy. Indian J Orthop 2010;44:148-58.
24. Al-Eisa E, Egan D, Deluzion K, Wassersug R. Effects of pelvic asymmetry and low back pain on trunk kinematics during sitting: a comparison with standing. Spine 2006;31:135-44.
25. Mulligan BR. Mobilization with movement. J Man Manipulative Ther 1993;1:154-6.
26. Williamson E. Fear Avoidance Belief Questionnaire (FABQ). Aust J Physiother 2006;52:149.