ORIGINAL RESEARCH

Serial Case Reporting Yoga for Idiopathic and Degenerative Scoliosis

系列案例报告瑜伽治疗特发性和退行性脊柱侧弯

Informe de serie de casos sobre el yoga para la escoliosis idiopática y degenerativa

Loren M. Fishman, MD, *United States*; Erik J. Groessl, PhD, *United States*; Karen J. Sherman, PhD, MPH, *United States*

Author Affiliations
Columbia College of Physicians and Surgeons New York (Dr Fishman); University of California San Diego, VA San Diego Healthcare System (Dr Groessl); Karen J. Sherman, PhD, MPH, Group Health Research Institute, Seattle, Washington.

Correspondence
lorenmartinfishman@gmail.com

Citation
Global Adv Health Med. 2014;3(5):16-21. DOI: 10.7453/gahmj.2013.064

Key Words
Scoliosis, yoga, adolescent idiopathic, degenerative

ABSTRACT

Background: Non-surgical techniques for treating scoliosis frequently focus on realigning the spine, typically by muscular relaxation or muscular or ligamentous stretching. However, such treatments, which include physical therapeutic, chiropractic, and bracing techniques, are inconsistently supported by current evidence. In this study, we assess the possible benefits of asymmetrical strengthening of truncal muscles on the convex side of the scoliotic curve through a single yoga pose, the side plank pose, in idiopathic and degenerative scoliosis.

Methods: Twenty-five patients with idiopathic or degenerative scoliosis and primary curves measuring 6 to 120 degrees by the Cobb method had spinal radiographs and were then taught the side plank pose. After 1 week performing the pose with convexity downward for 10 to 20 seconds, they were instructed to maintain the posture once daily for as long as possible on that one side only. A second series of spinal radiographs was taken 3 to 22 months later. Pre- and post-yoga Cobb measurements were compared.

Results: The mean self-reported practice of the yoga pose was 1.5 minutes per day, 6.1 days per week, for a mean follow-up period of 6.8 months. Among all patients, a significant improvement in the Cobb angle of the primary scoliotic curve of 32.0% was found. Among 19 compliant patients, the mean improvement rose to 40.9%. Improvements did not differ significantly among adolescent idiopathic and degenerative subtypes (49.6% and 38.4%, respectively).

Conclusions: Asymmetrically strengthening the convex side of the primary curve with daily practice of the side plank pose held for as long as possible for an average of 6.8 months significantly reduced the angle of primary scoliotic curves. These results warrant further testing.

摘要

背景：治疗脊柱侧弯的非手术方法常常注重通过肌肉松弛或拉伸肌肉或韧带而重新调整脊柱的方面。然而，目前的证据显示，这些物理治疗、脊柱推拿和支撑术等方法的效果不稳定。本研究中，我们在特发性和退行性脊柱侧弯中，评估侧面平板式的瑜伽姿势对于非对称加强脊柱侧弯凸侧躯干肌肉的益处。

方法：25名特发性或退行性脊柱侧弯经Cobb法测量原发曲度为6度至120度的患者，进行脊椎X光片，之后获教授侧面平板式姿势。姿态保持凸面向下10至20秒，练习一周，之后指导患者每日尽可能长时间地仅在一侧脊柱的保持该姿势。3到22个月以后，拍摄第二次脊柱X光片系列。对比做瑜伽姿势前后的Cobb测量值。

结果：患者自我报告做瑜伽姿势的时间平均为每天1.5分钟、每周6.1天，患者的平均随访时间为6.8个月。在所有患者中，发现32.0%出现脊柱侧弯原发曲度的Cobb角度值显著改善。在19例有主诉的患者中，平均改善率上升为40.9%。 在青少年的特发性和退行性亚型患者中，改善之间未见显著差别（分别为49.6%和38.4%）。

结论：平均6.8个月的每日尽可能长时间的进行侧面平板式姿势的不对称增强凸侧面的练习，会显著减小脊柱侧弯的原发曲度。这些结果需要进一步的测试。

SINOPSIS

Antecedentes: Las técnicas sin cirugía para el tratamiento de la escoliosis normalmente se centran en la realineación de la columna; por lo general, mediante la relajación muscular o el estiramiento muscular o de los ligamentos. Sin embargo, estos tratamientos, que incluyen la terapia física, quiropráctica y otras técnicas de refuerzo, son incompatibles de acuerdo con las evidencias actuales. En este estudio, se evalúan los posibles beneficios de fortalecer los músculos del tronco de manera asimétrica en el lado convexo de la curva escoliótica a través de una única postura de yoga, la tabla lateral, para la escoliosis idiopática y degenerativa.

Métodos: A 25 pacientes con escoliosis degenerativa o idiopática y con curvas escolióticas de 6 hasta 120 grados según el método de Cobb se les hizo radiografías de la columna y se les enseñó a practicar la postura de yoga “tabla lateral”. Después de haberla practicado durante una semana con convexidad hacia abajo durante 10/20 segundos, se les enseñó a mantener la postura una vez al día durante todo el tiempo que pudiesen solo por ese mismo lado. Entre 3 y 22 meses más tarde se volvieron a hacer radiografías por segunda vez. Se compararon las medidas con el método de Cobb antes y después de haber practicado yoga.

Resultados: La experiencia media de autoevaluación de la postura de yoga fue de 1,5 minutos por día, 6,1 días por semana, durante un periodo de seguimiento medio de 6,8 meses. Entre todos los pacientes, se experimentó una mejora significativa de un 32,0 % en el ángulo de Cobb de la curva escoliótica primaria. Entre 19 pacientes colaboradores, la mejoría

media alcanzó un 40,9 %. No hubo diferencias significativas de las mejorías entre los subtipos adolescentes idiopáticos y degenerativos (un 49,6 % y un 38,4 %, respectivamente). Conclusiones: Al fortalecer asimétricamente el lado convexo de la curva primaria con la práctica diaria de la postura "tabla lateral" de yoga intentando mantenerla el máximo de tiempo posible durante una media de 6,8 meses se consigue reducir significativamente el ángulo de las curvas escolióticas primarias. Estos resultados deben seguir investigándose.

INTRODUCTION

Scoliosis is a condition in which there is lateral curvature of the vertebral column. This right-to-left asymmetry is often accompanied by a rotational and/or kyphotic component.[1]

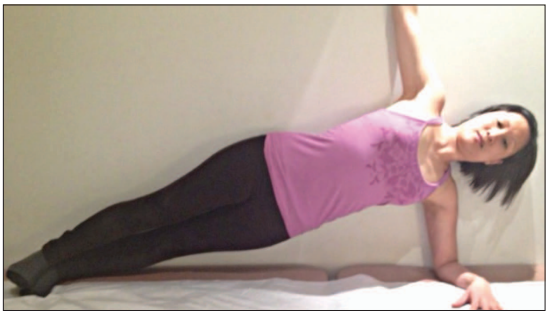
Scoliosis affects 2% to 3% percent of the population, or an estimated 6 to 9 million people in the United States. Medical and preventive advances in tuberculosis and polio have changed the statistics so that at present more than 80% of cases are idiopathic.[1,2] Currently most scoliosis develops in infancy or early childhood. Although it is generally discovered in the age range of 10 to 15 years, it usually begins considerably earlier, and at the time of its origin, is equally common in males and females.[1-3] Females, however, are eight times more likely to progress to a scoliotic curve of a magnitude that requires treatment.[1-3] Degenerative adult scoliosis results from a combination of age and deterioration of the spine, generally with onset after the age of 40 years. It may be related to osteoporosis.[4]

TREATMENT OF SCOLIOSIS

When untreated, scoliosis can be painful and can affect gait, posture, and other areas of physical functioning, measurably lowering self-esteem,[5-10] negatively affecting body image in teenagers,[9] and progressing to severely reduced respiratory function in aging populations.[11] Recent studies predict as much as a 7% annual increase in untreated scoliotic curves.[10-14] The standard of care recommends observation of patients with curves of less than 25 degrees, bracing of patients with curves in the 25 to 45–degree range, and surgery for patients with curves greater than 45 degrees.[14]

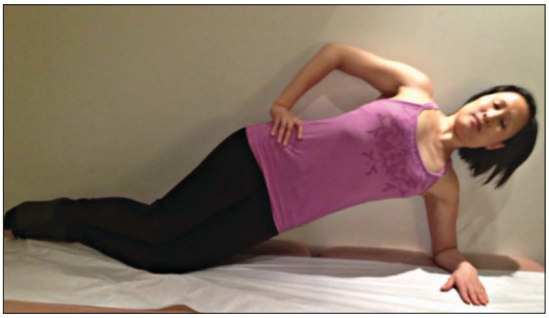
The studies evaluating the efficacy of bracing and other conservative therapies are inconsistent, and thus their findings must be regarded as inconclusive.[15-28] Several small studies are optimistic about yoga-like

Figure 1 The classical Iyengar side plank pose with the addition of the ribs raised vertically.

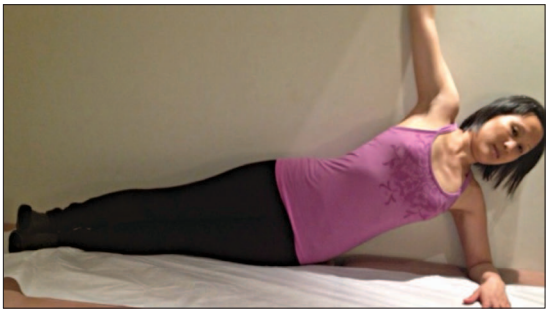


(a) Patients with carpal tunnel syndrome, arthritic wrists, or rotator cuff syndrome used this adaptation. Convex side downward, ribs are still elevated as in Figure 1.

(b) This adaptation was used for patients with weakness and imbalance.



(c) An adaptation for patients with knee and ankle pain.



(d) An adaptation for patients with knee pathology, in which the body weight was supported by the hip.

Figure 2 Four modifications of the side plank pose that were used when appropriate for patients with various co-morbid conditions.

(a) Complex curves require opposite side strengthening, accomplished in this way.

(b) The double-curve treatment may be adapted for limited shoulder function

Figure 3 Adaptations of the plank pose: (a) for complex curves and (b) for complex curves and limited shoulder function.

approaches.[17,25,26] Typical surgical treatments involve spinal fusion and/or wiring, with or without rods. Surgery brings a 44% to 59% reduction of the curves on which it is performed.[29-36] However, there is substantial comorbidity, including restriction of spinal mobility, hardware malfunctioning, extra strain on the vertebrae above and below the fusion, and pseudoarthroses. A recent study documented a rate of 50% of revision surgery following Cotrel-Dubousset surgical intervention.[33] The cost of the surgery, which is performed 38 000 times annually, varies from $125 000 to $250 000.[3] Estimating the average cost at $187 500, the total annual cost for surgery in the United States would be $7 125 000 000.[1,37]

For 3 to 22 months, we evaluated the effectiveness of regular home practice of a single yoga pose designed to strengthen the convex side of primary thoracolumbar curves. We began this study after observing that the side plank pose, done with the convex side down, had arrested and begun to reverse the natural progression of idiopathic and degenerative scoliosis in several patients.

METHODS

Patient Selection

We examined 25 consecutive patients in a retrospective study from the records of our private practice physical medicine and rehabilitation clinic in New York City, which is located in a neighborhood of affluent and educated people. We included adults with a documented scoliotic curve of 6 or more degrees, the willingness to perform the pose at least once daily for the entire study period, and the commitment to have initial and terminal scoliosis radiographs. Several of these patients did not follow the protocol. Among our candidates, patients with non-idiopathic, non-degenerative scoliosis, previous spinal surgery, pregnancy, or concurrent musculoskeletal or neuromuscular or psychiatric disorders were excluded from the study, as well as any persons we judged unable to perform the requisite exercises daily. Four patients were self-referred; the other 21 patients were referred by healthcare providers. We defined a noncompliant patient as one who did the side plank pose fewer than 4 times weekly.

Intervention

A slight modification of the classical Iyengar side plank pose was used[38] wherein patients were instructed to elevate their ribs, which is not part of the classical Iyengar technique (Figure 1). In addition, the pose was modified for other medical conditions and for weakness (Figure 2). Complex or "S-shaped" curves were treated by adding a second contralateral strengthening pose that consisted of holding the free leg with the free arm, and bulging that part of the spine, generally the cervicothoracic spine, upward (Figure 3).

Study Procedures

Before treatment, the study patients were referred for scoliosis radiographs. Their local radiologists or orthopedic surgeons were asked to read and record the Cobb angles and send the radiographs to our clinic. Patients were then taught the side plank pose and instructed to perform it for 10 to 20 seconds daily for 1 week, and to perform it once daily for as long as possible thereafter. Between 3 to 22 months following their initial radiographs, study patients returned to their radiologists or orthopedic surgeons for a second set of scoliosis radiographs. The radiologists or orthopedic surgeons read and recorded Cobb angles and sent the radiographs to us.

Measures

The authors re-measured the Cobb angles and agreed to consult the original radiologist or orthopedic surgeon if our measurements differed from theirs by more than 5 degrees. Compliant patients were defined as those who reported performing the side plank pose at least 4 times per week for the entire follow-up period.

Statistical Analysis

Using paired sample *t*-tests, the mean change in primary and secondary Cobb angles were compared for all patients. Differences over time between degenerative and idiopathic scoliosis were compared using repeated measures analysis of covariance (ANCOVA). Differences over time between compliant and noncompliant patients were also compared using repeated measures ANCOVA. Age and gender were examined as covariates.

RESULTS

Our study included 25 patients between the ages of

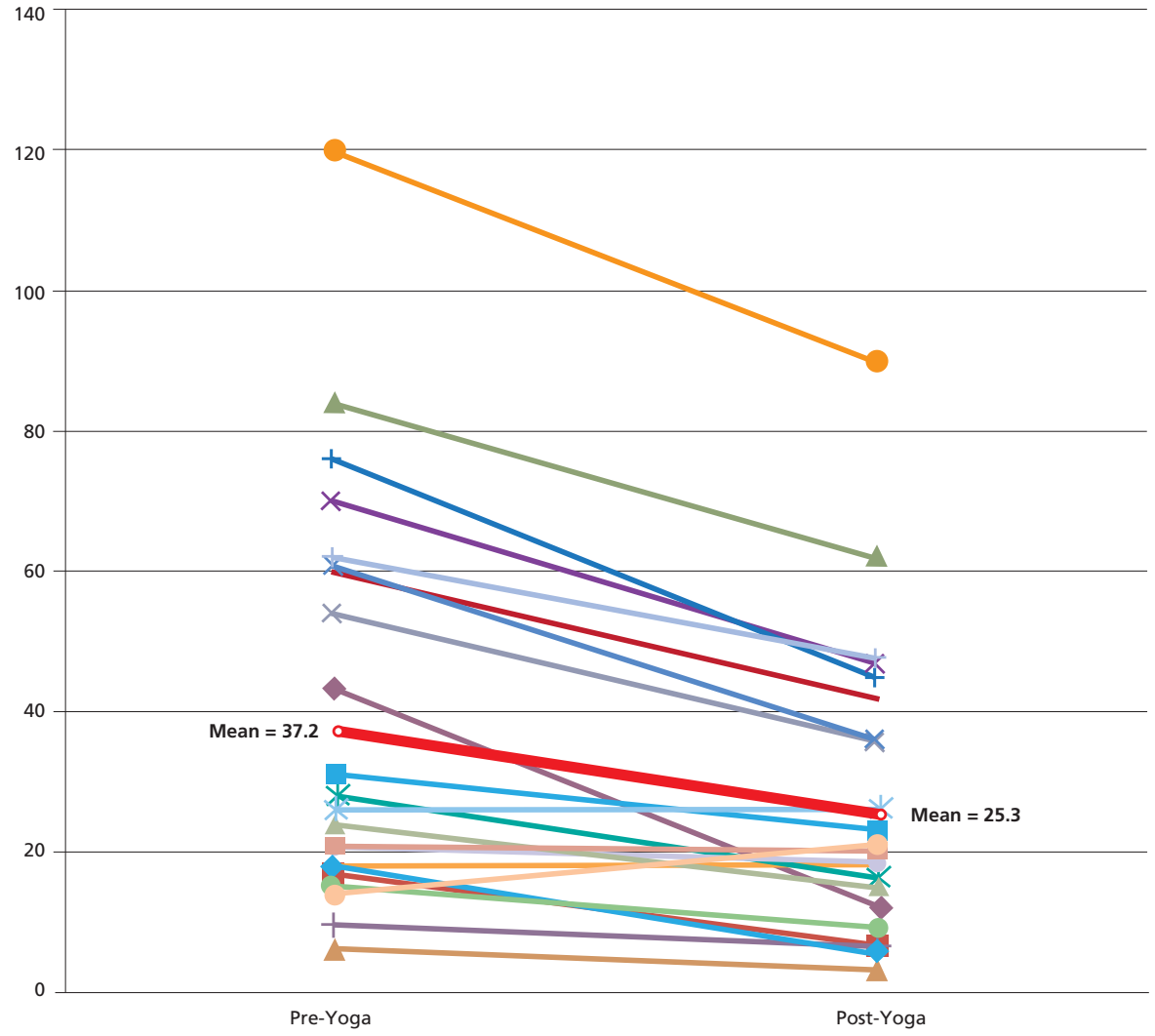


Figure 4 Improvement in Cobb angles of primary curve over an average of 6.8 months of daily practice of the side plank pose.

14 and 85 years (mean age of 52.1 y). The group included 23 white patients, one black patient, and one Asian American patient. Seven patients had secondary curves. Twelve primary curves and two secondary curves were convex to the right. For all patients, our spinal angle measurements and those made by the patient's radiologist or orthopedist were within 3 degrees. At the time of their second scoliosis radiographs, patients had been practicing the side plank pose nearly daily (average of 6.1 d per wk; range 5 to 7 d) for an average of 1.5 minutes (range 50 sec to 4 min).

All Patients

At baseline, the average Cobb angle for the primary curves was 37.2 degrees (range 6 to 120 degrees; SD 28.7) for the 25 patients. After practicing the plank pose for a mean of 6.8 months, the mean Cobb angle for the primary curve decreased to 25.3 degrees (range 3 to 90 degrees; SD 21.0), indicating primary curve improvement of 11.9 degrees or 32.0% (range: –50% to 72.1%; SD 18.5%). $P<.001$). At baseline, the mean Cobb angle for the seven secondary curves was 38.3 degrees (SD 37.7) while the comparable angle after the yoga intervention was 29.7 degrees (SD 28.0), a reduction of 8.6 degrees, or 26%; $P=.108$ (Table 1 and Figure 4).

Table 1 Changes in Primary Cobb Angle of All Patients With Follow-up Data

	Pre Mean (SD)	Post Mean (SD)	Mean difference	% change	df	*t* score	*P* value
Primary Angle (n=25)	37.2 (28.7)	25.3 (21.0)	11.9	32.0%	21	5.25	<.001
Secondary Angle (n =7)	38.3 (37.7)	29.7 (28.0)	8.6	22.5%	6	1.89	.108

Effect of Compliance

As shown in Table 2, there were substantial baseline differences between the Cobb angles of patients who were deemed compliant vs non-compliant. Compliant patients had significantly greater improvement in the Cobb angle of their primary curve (40.9% vs 0.5%; $P=.014$).

Table 2 Changes in Primary Cobb Angle of Patients by Self-reported Compliance

	Pre Mean (SD)	Post Mean (SD)	Mean difference	% change	df	F score	*P* value
Did the pose (n=20)	40.5 (31.1)	25.4 (23.5)	15.1	40.9% (14.8)	1	7.26	.014
Did not do pose (n =5)	27.0 (17.6)	25.1 (11.4)	1.9	0.46% (18.5)			

Adolescent Idiopathic Scoliosis and Degenerative Scoliosis

We limited our analysis of these two scoliosis subtypes to compliant patients only. Both groups showed significant improvement in primary curve angles from baseline to the post-yoga follow-up measurement. As shown in Table 3, the groups did not differ significantly in the amount of improvement, with degenerative scoliosis patients improving 38.6% and adolescent idiopathic scoliosis patients improving 49.6%.

Compliant Patients With Adolescent Idiopathic Scoliosis

At baseline, the mean Cobb angle for the primary curves in the seven compliant patients with idiopathic scoliosis was 22.8 degrees (range 6 to 43 degrees; SD 13). After patients practiced the unilateral side plank pose for an average of 6.5 months, the mean Cobb angle decreased to 11.2 degrees (range 3 to 23 degrees; SD 7.2), a primary curve improvement of 49.2% (range 0% to 72.1%; SD 18.6.) ($P<.001$ for primary curve reduction, Table 3).

Table 3 Changes in Primary Cobb Angle by Type of Scoliosis Among Compliant Patients

	Pre Mean (SD)	Post Mean (SD)	Mean difference	% change	df	F score	*P* value
Degenerative (n=12)	50.4 (36.3)	33.1 (27.6)	17.3	38.4%	1	0.447	.511
Idiopathic (n =7)	22.8 (13)	11.2 (7.2)	11.6	49.6% (18.6)			

Compliant Patients With Degenerative Scoliosis

Among the 12 compliant patients with degenerative scoliosis, the average Cobb angle at baseline of the primary curves was 50.4 degrees (range 10 to 120 degrees; SD 36.3). After an average of 4.9 months of practice, their mean primary Cobb angle decreased to 33.1 degrees (range 7 to 90 degrees; SD 27.6), indicating mean primary curve improvement of 38.4% (range 25% to 70%, Table 3).

DISCUSSION

In this case series, we found significant improvements in the Cobb angle of the primary scoliotic curve among 25 consecutive patients who were prescribed a single yoga pose. The limited number of patients with secondary curves showed some additional benefit to the secondary curve as well. Interestingly, this occurred over a relatively short time period, with a mean follow-up of 6.8 months and as little as 3 to 6 months in many patients. Among our 19 compliant patients, 7 had sufficiently large scoliotic curves that they might be surgical candidates (ie, Cobb angles of ≥45 degrees) and another three had large curves sufficient enough that bracing would be appropriate (ie, Cobb angles ≥25 degrees and <45 degrees[1-3]). Untreated scoliosis is believed to progress to more severe spinal curvature over time.[10-13] It appears that the improvements of the magnitude that we found (32% on average) would eliminate the need for surgery or bracing in most of these patients.

Possible Mechanism

To understand why this yoga pose may help in scoliosis, it is important to conceptualize the physics involved in creating scoliotic curves. A simplified analysis of how humans stand erect involves the symmetrical downward pull of the dorsal, abdominal, intercostal, and paraspinal muscles. Scoliosis, then, could be explained by asymmetry in the force these muscles exert on the spine. The spine will bend toward the stronger side, and thus, the muscles of the convex side may be weaker than their smaller-appearing counterparts on the concave side (Figure 5). We speculate that the side plank pose is useful for strengthening the convex side's quadratus lumborum, iliopsoas, transverses abdominus, oblique, intercostal, and paraspinal musculature, which, in turn, might straighten the spine (Figure 5).

Limitations

Drawing firm conclusions from a small case series is challenging. In this study, we lacked both a control group and detailed notes on adherence to the treatment. However, it is notable that the reductions in the Cobb angle observed in these patients are superior to those from

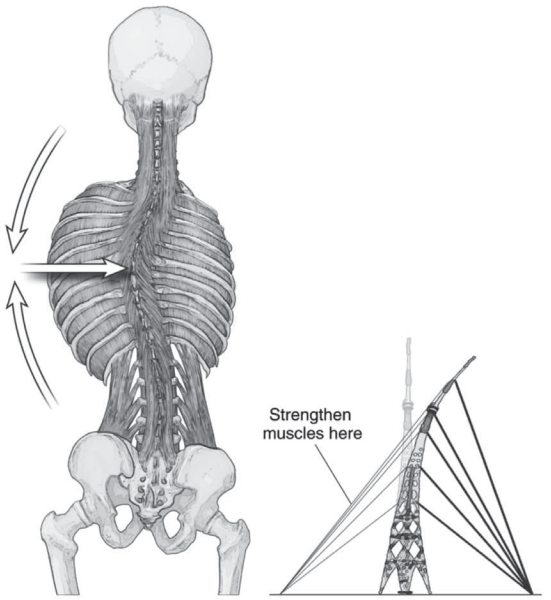


Figure 5 Conceptualization of scoliosis and mechanism of correction.

all the therapeutic studies of conservative treatments we identified and all but one therapeutic study of bracing.[19] There may be added value for adolescents because the daily home practice of these poses is unlikely to raise the same psychological and self-esteem issues that occur with bracing as a treatment. Yoga involves no encumbrance or restriction of movement in daily life and no visible markers of practice. While the best surgical studies show 59% improvement for patients, our study could not determine how much total improvement would be seen if the side plank pose were carried out for a longer period of time. The relative ease and low cost of practice might prompt some parents and children to begin treatment earlier. As a result, some scoliotic curves might never advance to the degree that requires surgical correction. In addition, use of the side plank pose has no notable side effects apart from occasional and mild wrist and shoulder discomfort. We therefore believe that future studies of this intervention are warranted to determine the factors that promote success of the procedure and its longevity.

Future Studies

Future studies of yoga as a treatment for scoliosis would benefit from inclusion of Lehnke classification, which is used to determine surgical suitability by measuring the primary (largest) curve. In addition, future randomized studies in adolescent idiopathic scoliosis should include Risser sign, a measure of hip socket and iliac bone growth that serves as a proxy for full skeletal maturity. Use of these measures will help make these studies comparable to surgical studies. In addition, studies with longer follow-up periods are needed to clarify the relationship between duration of treatment to the length of improvement and the possible side effects of prolonged treatment. Because past investigations found that both bracing and surgery impacted quality of life,[5-10] including quality-of-life measures would further facilitate comparability to more traditional studies and may help patients and if applicable, their parents, with decision making about the most appropriate treatments.

REFERENCES

1. National Scoliosis Foundation. Information and support http://www.scoliosis.org/info.php. Accessed July 3, 2014.
2. Linker B. A dangerous curve: the role of history in America's scoliosis screening programs. Am J Public Health. 2012;102(4):606-16.
3. Stolinski L, Kotwicki T. Trunk asymmetry in one thousand school children aged 7-10 years. Stud Health Technol Inform. 2012;176:259-63.
4. University of Maryland Medical Center. Degenerative adult scoliosis. http://umm.edu/programs/spine/health/guides/degenerative-adult-scoliosis#ixzz2nmnJiava. Accessed July 3, 2014.
5. Kinel E, Kotwicki T, Podolska A, Białek M, Stryła W. Quality of life and stress level in adolescents with idiopathic scoliosis subjected to conservative treatment. Stud Health Technol Inform. 2012;176:419-22.
6. Misterska E, Glowacki M, Latuszewska J. Female patients' and parents' assessment of deformity- and brace-related stress in the conservative treatment of adolescent idiopathic scoliosis. Spine (Phila Pa 1976). 2012;37(14):1218-23.
7. Negrini S, Donzelli S, Dulio M, Zaina F. Is the SRS-22 able to detect Quality of Life (QoL) changes during conservative treatments? Stud Health Technol Inform. 2012;176:433-6.
8. Parsch D, Gärtner V, Brocai DR, Carstens C, Schmitt H. Sports activity of patients with idiopathic scoliosis at long-term follow-up. Clin J Sport Med. 2002 Mar;12(2):95-8.
9. Pinquart M. Body image of children and adolescents with chronic illness: A meta-analytic comparison with healthy peers. Body Image. 2012 Dec 6. pii: S1740-1445(12)00137-4.
10. Fu KM, Smith JS, Polly DW Jr, et al.Morbidity and mortality in the surgical treatment of 10,329 adults with degenerative lumbar stenosis. J Neurosurg Spine. 2010 May;12(5):443-6.
11. Dubousset J. Idiopathic scoliosis. Definition—pathology—classification—etiology. Bull Acad Natl Med. 1999;183(4):699-704.
12. Chuah SL, Kareem BA, Selvakumar K, Oh KS, Borhan Tan A, Harwant S. The natural history of scoliosis: curve progression of untreated curves of different aetiology, with early (mean 2 year) follow up in surgically treated curves. Med J Malaysia. 2001;56 Suppl C:37-40.
13. Weinstein SI, Dolan LA, Spratt KF, Peterson KK, Spoonamore MJ, Ponseti IV. Health and function of patients with untreated scoliosis: a 50 year natural history study. JAMA. 2003;289(5):559-67.
14. Lenke LG. Commentary: continuing the quest for identifying specific criteria for the progression of adolescent idiopathic scoliosis. Spine J. 2012;12(11):996-7.
15. Fu KM, Smith JS, Sansur CA, Shaffrey CI. Standardized measures of health status and disability and the decision to pursue operative treatment in elderly patients with degenerative scoliosis. Neurosurgery. 2010;66(1):42-7; discussion 47.
16. Felse RJ. An inquiry into chiropractors' intention to treat adolescent idiopathic scoliosis. J Manipulative Physiol Ther. 2001;24:177-82.
17. Romano M, Minozzi S, Bettany-Saltikov J, et al. Exercises for adolescent idiopathic scoliosis. Cochrane Database Syst Rev. 2012;8:CD007837.
18. Weiss HR, Werkmann M. Rate of surgery in a sample of patients fulfilling the SRS inclusion criteria treated with a Chêneau brace of actual standard. Stud Health Technol Inform. 2012;176:407-10.
19. Szwed A, Kołban M. Results of SpineCor dynamic bracing for idiopathic scoliosis. Stud Health Technol Inform. 2012;176:379-82.
20. Weiss HR. Inclusion criteria for physical therapy intervention studies on scoliosis - a review of the literature. Stud Health Technol Inform. 2012;176:350-3.
21. Weiss HR, Goodall D. The treatment of adolescent idiopathic scoliosis (AIS) according to present evidence. A systematic review. Eur J Phys Rehabil Med. 2008;44(2):177-93.
22. Aulisa AG, Guzzanti V, Perisano C, Marzetti E, Falciglia F, Aulisa L. Treatment of lumbar curves in scoliotic adolescent females with progressive action short brace: a case series based on the Scoliosis Research Society Committee Criteria. Spine (Phila Pa 1976). 2012;37(13):E786-91.
23. Weiss HR. Physical therapy intervention studies on idiopathic scoliosis-review with the focus on inclusion criteria1. Scoliosis. 2012;7(1):4
24. Czupryna K, Nowotny-Czupryna O, Nowotny J. Neuropathological aspects of conservative treatment of scoliosis. A theoretical view point. Ortop Traumatol Rehabil. 2012 Mar-Apr;14(2):103-14.
25. Pugacheva N. Corrective exercises in multimodality therapy of idiopathic scoliosis in children - analysis of six weeks efficiency—a pilot study. Stud Health Technol Inform. 2012;176:365-71.
26. Bettany-Saltikov J1, Parent E, Romano M, Villagrasa M. Physiotherapeutic scoliosis-specific exercises for adolescents with idiopathic scoliosis. Eur J Phys Rehabil Med. 2014 Feb;50(1):111-21.
27. Donzelli S, Lusini M, Zaina F. Characteristics of patients with more than 20° of improvement or worsening during conservative treatment of adolescent idiopathic scoliosis. Stud Health Technol Inform. 2012;176:354-717.
28. Miller DJ, Franzone JM, Matsumoto H, et al. Electronic monitoring improves brace-wearing compliance in patients with adolescent idiopathic scoliosis: a randomized clinical trial. Spine (Phila Pa 1976). 2012;37(9):717-21.
29. Basu S, Rathinavelu S, Baid P. Posterior scoliosis correction for adolescent idiopathic scoliosis using side-opening pedicle screw-rod system utilizing the axial translation technique. Indian J Orthop. 2010;44(1):42-9.
30. Kelly DM, McCarthy RE, McCullough FL, Kelly HR. Long-term outcomes of anterior spinal fusion with instrumentation for thoracolumbar and lumbar curves in adolescent idiopathic scoliosis. Spine (Phila Pa 1976). 2010;35(2):194-8.
31. Good CR, Lenke LG, Bridwell KH, O'Leary PT, Pichelmann MA, Keeler KA, Baldus CR, Koester LA. Can posterior-only surgery provide similar radiographic and clinical results as combined anterior (thoracotomy/thoracoabdominal)/posterior approaches for adult scoliosis? Spine (Phila Pa 1976). 2010;35(2):210-8
32. Xie J, Wang Y, Zhao Z, et al. Posterior vertebral column resection for correction of rigid spinal deformity curves greater than 100°. J Neurosurg Spine. 2012;17(6):540-51.
33. Stokes IA, McBride C, Aronsson DD, Roughley PJ. Intervertebral disc changes with angulation, compression and reduced mobility simulating altered mechanical environment in scoliosis. Eur Spine J. 2011;20(10):1735-44.
34. Kelly DM, McCarthy RE, McCullough FL, Kelly HR. Long-term outcomes of anterior spinal fusion with instrumentation for thoracolumbar and lumbar curves in adolescent idiopathic scoliosis. Spine (Phila Pa 1976). 2010;35(2):194-8.
35. Patel PN, Upasani VV, Bastrom TP, et al. Spontaneous lumbar curve correction in selective thoracic fusions of idiopathic scoliosis: a comparison of anterior and posterior approaches. Spine (Phila Pa 1976). 2008;33(10):1068-73.
36. Mueller FJ, Gluch H. Cotrel-Dubousset instrumentation for the correction of adolescent idiopathic scoliosis. Long-term results with an unexpected high revision rate. Scoliosis. 2012;7(1):13.
37. Kepler CK, Wilkinson SM, Radcliff KE, et al. Cost-utility analysis in spine care: a systematic review. Spine J. 2012 Aug;12(8):676-90.
38. Iyengar BKS. Light on yoga. New York: Schocken Books; 1966:309-11.