ACRM
AMERICAN CONGRESS OF REHABILITATION MEDICINE

Archives of Physical Medicine and Rehabilitation

journal homepage: www.archives-pmr.org

Archives of Physical Medicine and Rehabilitation 2015;■:■

Letter to the Editor

Prevalence and Predictors of Adolescent Idiopathic Scoliosis in Adolescent Ballet Dancers

We compliment Longworth et al[1] for their article that we read with interest and would like to comment on. Recently, we published an article that applied a similar methodology and showed an association between swimming, spinal deformities, and low back pain.[2] Even though we used a cutoff of 7° Bunnell that is usually applied in the most selective school screening,[3] we did not report any association between scoliosis and swimming, because we did not perform radiography to confirm the diagnosis. We called these findings "trunk asymmetries."[4] We think that this should also be the case in this study of dance.

By applying a cutoff of 5° Bunnell in our study, we found 43% with an ATR equal or larger in the control group, which was taken from the school. This is much larger than the 3% found in the control group in the present study and could be explained by the small sample size. Also, the age range (10–18 years) was quite large. 5° Bunnell of ATR is not so relevant when a girl is 18, but can signify a risky condition at the age of 10 to 12 years. Therefore, we suggest focusing on a narrower age range.

Furthermore, there are some concerns about sampling: The use of a flier to recruit such a small study group could introduce selection bias; the control group runs a similar risk, because we cannot be sure that this small population is really representative of the target population. Moreover, the population is really small for a disease that has a prevalence of 2% to 3% in adolescents, even if a sample size calculation has been made. In our view, a larger study with a control group more representative of the general population should be undertaken to confirm these interesting but still preliminary data.

In conclusion, even if the data are in line with those of other studies of sports with similar features,[5,6] we wonder how far these findings are due to selection bias.

We would be grateful if we could have more information and comments from the authors.

Fabio Zaina, MD
Sabrina Donzelli, ■
Michele Romano, ■
Stefano Negrini, ■
■■■

Disclosures: none.

References

1. Longworth B, Fary R, Hopper D. Prevalence and predictors of adolescent idiopathic scoliosis in adolescent ballet dancers. Arch Phys Med Rehabil 2014;95:1725-30.
2. Zaina F, Donzelli S, Lusini M, Minnella S, Negrini S. Swimming and spinal deformities: a cross-sectional study. J Pediatr 2015;166:163-7.
3. Vernacchio L, Trudell EK, Hresko MT, Karlin LI, Risko W. A quality improvement program to reduce unnecessary referrals for adolescent scoliosis. Pediatrics 2013;131:e912-20.
4. Grivas TB, Vasiliadis ES, Koufopoulos G, Segos D, Triantafyllopoulos G, Mouzakis V. Study of trunk asymmetry in normal children and adolescents. Scoliosis 2006;1:19.
5. Tanchev PI, Dzherov AD, Parushev AD, Dikov DM, Todorov MB. Scoliosis in rhythmic gymnasts. Spine 2000;25:1367-72.
6. Warren MP, Brooks-Gunn J, Hamilton LH, Warren LF, Hamilton WG. Scoliosis and fractures in young ballet dancers: relation to delayed menarche and secondary amenorrhea. N Engl J Med 1986;314:1348-53.

http://dx.doi.org/10.1016/j.apmr.2015.02.030

ACRM
AMERICAN CONGRESS OF REHABILITATION MEDICINE

Archives of Physical Medicine and Rehabilitation

journal homepage: www.archives-pmr.org

Archives of Physical Medicine and Rehabilitation 2014;95:1725-30

ORIGINAL ARTICLE

Prevalence and Predictors of Adolescent Idiopathic Scoliosis in Adolescent Ballet Dancers

Brooke Longworth, BSc, Robyn Fary, PhD, Diana Hopper, PhD

From the School of Physiotherapy and Exercise Science, Curtin University, Perth, WA, Australia.

Abstract

Objective: To determine any differences between the prevalence of adolescent idiopathic scoliosis in ballet dancers who are girls compared with age-matched nondancers, and to establish if any relations exist between the presence of scoliosis and generalized joint hypermobility, age of menarche, body mass index (BMI), and the number of hours of dance training per week.

Design: Cross-sectional, matched pair study.

Setting: Dance school.

Participants: Dancers (n = 30) between the ages of 9 and 16 years were recruited from a certified dance school in Western Australia; each dancer provided a consenting age-matched nondancer (n = 30).

Interventions: Not applicable.

Main Outcome Measures: Measurements were taken for angle of trunk rotation using a scoliometer (presence of scoliosis) and for height and weight to produce generalized joint hypermobility using Beighton criteria and an age-adjusted BMI, respectively. A subjective questionnaire regarding age of menarche and participation in dance and other sports was completed.

Results: Thirty percent of dancers tested positive for scoliosis compared with 3% of nondancers. Odds ratio calculations suggest that dancers were 12.4 times more likely to have scoliosis than nondancers of the same age. There was a higher rate of hypermobility in the dancer group (70%) compared with the nondancers (3%); however, there were no statistically significant relations between scoliosis and hypermobility, age of menarche, BMI, or hours of dance per week.

Conclusions: Adolescent dancers, similar to adult dancers, are at significantly higher risk of developing scoliosis than nondancers of the same age. Vigilant screening and improved education of dance teachers and parents of dance students may be beneficial in earlier detection and, consequently, reducing the risk of requiring surgical intervention.

Archives of Physical Medicine and Rehabilitation 2014;95:1725-30

Adolescent idiopathic scoliosis (AIS) is a 3-dimensional, structural curvature of the spine, with lateral and rotational components, arising at pubescence without definitive cause.[1] Worldwide, the reported prevalence of AIS varies from .47% to 5.2%, with 1 study stating a prevalence as high as 9.2%.[2,3] The prevalence of AIS in Australia is reported between 1.5% and 10% and represents 90% of all scoliosis.[4,5] It is significantly more common in women, especially in curves exceeding 30°.[5] Clinical indicators for AIS (eg, lateral curvature, rib hump, hip and shoulder asymmetries) typically appear early in adolescence and can lead to physical deformity and pain, reduced self-esteem, higher depression rates, and pulmonary compromise.[2,6-8]

Treatment of AIS varies depending on the degree of curvature, patient characteristics, and feasibility, with current methods, including monitoring and spinal bracing, and for progressive or unstable curves or curves expected to exceed 50° by skeletal maturity, surgery.[1,2] Evidence suggests that earlier detection is associated with a decreased rate of surgical treatment and fewer complications, including deformity, pain, pulmonary compromise, and reduced degree and complication of the curvature.[1,8]

Several studies report higher prevalence of AIS in adult classical ballet dancers who are women than the general population, finding scoliosis in 24% to 50% of adult participants.[9-11] Similar findings have been found in sports sharing similar characteristics to dance, including rhythmic gymnastics, where the incidence of scoliosis was reported to be 10 times that of a nongymnast group.[9,10] Several theories as to why such a high prevalence of

Disclosures: none.

0003-9993/14/$36 - see front matter © 2014 by the American Congress of Rehabilitation Medicine
http://dx.doi.org/10.1016/j.apmr.2014.02.027

scoliosis exists in dancers, with a range of sources suggesting that the tall, ectomorphic body composition, hypermobility, delayed maturation, and dietary abnormalities characteristic of dancers may be related.[11]

AIS is of unknown etiology; however, significant evidence suggests its development is multifactorial and may be associated with the many identified physical characteristics. Many genetic links have been demonstrated in the literature and appear to play a role; however, no single genetic locus has been identified; hence, a polygenetic influence is possible.[12-14] Research has also found links between AIS and generalized joint hypermobility and flexibility, delayed menarche, and low body mass index (BMI).[15] These characteristics are common (and desired) in dancers and have been associated with an increased incidence of scoliosis in professional dancers.[16]

Although several authors have noted markedly higher rates of AIS in adult professional dancers who are women compared with normative population values, evidence as to whether high rates exist in adolescent dancers is lacking.[17] Because patient outcomes improve with earlier detection and treatment, investigation to determine if there is a difference in the prevalence of AIS in adolescent dancers compared with age-matched nondancers could lead to earlier detection of scoliosis in dancers and improved health and career outcomes. Furthermore, investigation into whether physical characteristics found to be associated with scoliosis in previous literature (joint hypermobility, delayed menarche, low BMI) are related to the presence of scoliosis in the adolescent dancers being studied could help identify which characteristics may identify young dancers at risk of developing AIS.

The primary purpose of this study was to determine if there was a difference between the prevalence of AIS in adolescent, ballet dancers who are girls compared with age-matched nondancers. The secondary purpose of the study was to establish whether there is a relation between the presence of scoliosis and individual physical characteristics, namely generalized joint hypermobility, age of menarche, BMI, and the number of hours of dance classes and practice per week.

Methods

Study design

A cross-sectional study was used to compare the prevalence of scoliosis between a group of 30 adolescent dance students who are girls and 30 nondancers who are girls of comparative age and investigate the relation between scoliosis and the previously identified physical factors.

Participants

The study involved 60 healthy adolescents who are girls and between the ages of 9 and 16 years (mean, 12y). Thirty of these participants were adolescent dancers recruited via flyer advertising from certified dance schools in the southwest of Western Australia. In order to meet inclusion criteria for the study, the dancers needed a minimum of 3 years dance experience and participation in at least 4 hours of structured dance training per week under the tuition of a qualified dance teacher. Each recruited dancer was required to provide a consenting nondancer who had no involvement in dance, gymnastics, or calisthenics and was of the same age. All participants and a legal guardian signed an informed consent form prior to participation. This study was approved by the Curtin University Human Research Ethics Committee (PT218/2012).

Sample size

A priori calculations for the sample size of 60 were based on detecting a 30-point difference in the rate of scoliosis between the 2 groups that would mirror the difference in mean prevalence of scoliosis in adult ballet dancers and that in the general population with a power of 80% and alpha level of .05.

Outcome measures

Indication of scoliosis

To determine the presence of scoliosis, the angle of trunk rotation (ATR) was measured using an Orthopaedic Systems Baseline Scoliometer 5280[a] originally developed by Bunnell[18] and following the protocol described by Amendt[19] (fig 1). This specialized inclinometer is used to screen for the presence of scoliosis through detection of the vertebral and costal rotation integral to scoliosis, given it is defined as a 3-dimensional disorder.[1,18] An 8-year prospective study of 1065 patients concluded that the scoliometer has 87% sensitivity in detecting lateral curves exceeding 10° and 100% sensitivity in predicting spinal curvatures with Cobb angles exceeding 20° with an ATR of 5°, roughly indicating a curvature of $>20°$.[16,17] The scoliometer also has high interrater and intrarater reliability (.86−.97) and excellent reliability and sensitivity in detecting scoliosis, particularly where a double curve is present.[17] It is also nonionizing and relatively inexpensive and simple to use.[20] However, although the scoliometer's ability to detect the presence of curvature is excellent, the correlation to Cobb angle size, while statistically significant, is relatively weak; therefore, although the scoliometer is sufficient to

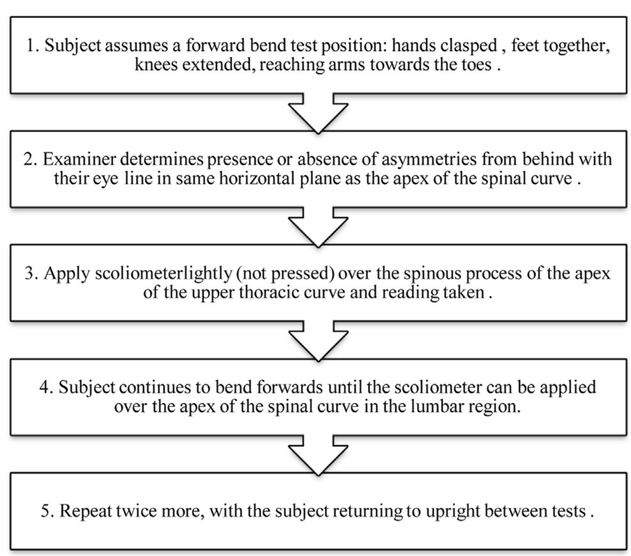

Fig 1 Method of measurement of the ATR using a scoliometer.

List of abbreviations:

AIS **adolescent idiopathic scoliosis**
ATR **angle of trunk rotation**
BMI **body mass index**

detect or disprove the presence of scoliosis, radiography to determine the Cobb angle is still required to determine the severity of the curve.[19,20] Furthermore, as the ATR cut-off decreases, specificity also decreases to 34% at a 5° cut-off.[20] However, a 5° ATR (indicating a Cobb angle of approximately 20°) has been established as a sufficient screening tool and evidence for referral for further investigation into progression risk factors.[20] Consequently, any participants who tested positive for scoliosis in our study were advised to seek medical advice; therefore, if appropriate, imaging could be conducted, given that the risk of missing a potentially progressive curvature outweighed any short-term anxiety associated with a false-positive indication of scoliosis. To measure the ATR, the chief examiner placed the scoliometer over the apex of the thoracic kyphosis and lumbar curves, and an external examiner read and recorded the ATR reading to ensure consistency. The measurement was taken 3 times; where the 3 readings were not consistent, an average of the 3 trials was taken. Per the recommendations from Amendt,[19] Bunnell,[18] and colleagues, the presence of visible asymmetry (indicating a rib hump deformity) or an ATR >5° was used for determining a positive result. The external examiner was not informed as to the cut-off point for a positive result, and the positive or negative result was allocated after data collection was completed. This procedure is summarized in figure 1.

Generalized hypermobility

Joint hypermobility was measured using the Beighton criteria by the trained external examiner.[21] Various Beighton cut-off points from 4 to 7 (out of 9) have been described to indicate hypermobility. However, to be consistent with the literature regarding hypermobility and scoliosis in ballet dancers and the recommendations of the Beighton criteria, this study used a score >4 (out of 9) to indicate generalized hypermobility.[19]

The Beighton criteria have been established as a simple and reliable measure of generalized joint hypermobility in healthy children and adolescents, with further increased accuracy when goniometry is used.[22] Consequently, goniometry (integrating the 5° of error for standard goniometry) was used to determine hyperextension of the elbow, knee, and metacarpophalangeal joints. The external examiner was trained in the use of goniometry in conjunction with the Beighton criteria using a universal goniometer.

Calculation of BMI

To attain a BMI score, height was measured by a Seca 217 stadiometer,[b] and weight was measured using Taylor digital lithium scales,[c] calibrated by a 2kg mass. The stadiometer and scales were kept consistent between all subjects. These measures were used to produce an age-adjusted BMI using the Centers for Disease Control and Prevention's children's BMI calculator spreadsheet.[23] Using the children's BMI calculator, subjects were then classified as underweight, healthy weight, overweight, or obese for their age. All measurements were taken with the participants' shoes removed. A blinded external examiner was trained prior to the study to ensure that height measurements were taken with the participant in the Frankfort plane.[24]

Subjective questionnaire

All participants completed a short questionnaire that was used to determine age in years, age at menarche, average hours of dance training and practice per week, and involvement and hours of participation in other sporting activities. They were preinstructed to answer no or 0 to any question that they did not understand, but they were permitted to ask for clarification if desired.

Procedure

Each dancer and nondancer pair tossed a coin to determine random order of testing. While one participant underwent testing of the physical measurements (presence of scoliosis, Beighton hypermobility criteria, height, weight), the other completed the subjective questionnaire in a holding area. Once the procedures were complete, participants swapped to complete the other measurements.

Data analysis

Data were analysed using SPSS version 19 for Windows,[d] and normalcy of the data was established. Descriptive analysis was conducted to assess the means and SDs of the dancers' and nondancers' demographics, physical characteristics, and training history. Chi-square analysis was used to determine any difference in the prevalence of scoliosis in the dance group compared with the nondancer group. For the secondary research aim, to determine if there was any association between presence of scoliosis and Beighton score, BMI, age of menarche, number of hours of dance training per week, and number of hours of dance practice per week, a logistic regression was used on the data from the dance group only.

Results

Sample characteristics showed homogeneity between the 2 groups for all characteristics except hypermobility with a Beighton score >4 (out of 9) for 21 dancers and 1 nondancer ($P=.04$) (table 1).

Nine dancers (30%; 95% confidence interval, 16.7%−47.9%) tested positive for scoliosis. In the nondancer group, only 1 participant (3.33%; 95% confidence interval, 0.5%−16.7%) tested positive. Chi-square analysis demonstrated a statistically significant difference in the presence of scoliosis between the 2 groups

Table 1 Baseline characteristics of the participants

Characteristic	Control (n=30)	Dancers (n=30)
Age, y	12.00±2.5	12.00±2.6
BMI, kg/m^{-2}	17.30±2.9	16.60±3.0
Age-adjusted BMI percentile, n (%)		
Underweight	4 (13.3)	7 (23.2)
Healthy	25 (83.3)	22 (73.3)
Overweight	1 (3.3)	0 (0.0)
Obese	0 (0.0)	1 (3.3)
Presence of hypermobility (Beighton >4)	1	21*
Age of menarche†	12.90±1.2	13.40±1.3
Dance hours	NA	6.13±2.0
Practice hours	NA	1.20±1.1
Other sports hours‡	1.83±2.1	0.80±1.1

NOTE. Values are mean ± SD or as otherwise indicated.
Abbreviation: NA, not applicable.
* $P=.04$.
† Controls (n=11) and dancers (n=9).
‡ $P=.02$.

(χ_1^2=7.7, P=.006, odds ratio=12.43). There were no significant relations between the presence of scoliosis and any of the measured physical characteristics (table 2). However, there was a trend toward significance in hours of dance practice (see table 2).

Discussion

This study demonstrated a significantly increased prevalence in scoliosis among adolescent ballet dancers compared with the nondancers, with dancers being >12 times more likely to have scoliosis. This echoes the high prevalence of scoliosis (24%–50%) found in previous professional adult ballet dancer cohorts.[9-11] This study clearly demonstrates that adolescent dancers are indeed displaying high rates of scoliosis; therefore, more vigilant screening measures are indicated.

Currently, there are no formal scoliosis screening programs in young dancers in Australia or widespread school screening programs.[4,22] Many professional companies screen dancers on entry; however, by this age, dancers have ceased skeletal growth and conservative interventions to limit spinal curvature are no longer viable.[18,25] Because our research clearly demonstrates high prevalence of scoliosis in the adolescent dancer, screening adolescent dancers in a similar fashion to professionals would be beneficial in terms of treatment options and outcomes.

Previous literature[9-11] suggests that the high rate of scoliosis found in adult dancers is related to certain predisposing physical characteristics (generalized joint hypermobility, delayed menarche, low BMI), which are common in dancers.

Hypermobility is considered a contributing factor in scoliosis as a result of altered collagen structure and cross-linking. This may compromise spinal integrity and predispose the individual to spinal instability and AIS development.[26] Czaprowski et al[27] found joint hypermobility in 51% of subjects diagnosed with AIS compared with 19% without AIS. Hypermobility is common and traditionally desired in dancers, with a particularly high prevalence in dance students.[28] Similar findings exist in rhythmic gymnasts.[10]

Likewise, significant relations between delayed menarche and AIS have been reported in previous research.[29] Consequently, sports associated with delayed menarche (eg, dance, rhythmic gymnastics) also report a high prevalence of scoliosis.[11,12] Warren et al[30] reported that 83% of dancers with scoliosis also had delayed menarche (≥14y old). It is suggested that delayed menarche contributes to scoliosis by extending the accelerated growth phase, during which risk of scoliosis and scoliosis progression is highest.[31] A relation between scoliosis and delayed menarche was not shown in our cohort of dancers, with only 3 of the 8 dancers aged >14 years (above which menarche is considered to be delayed) having a delayed menarche compared with 1 nondancer aged >14 years with delayed menarche. However, given the age restrictions of the study (ages 9–16y), there was a low number of participants (9 dancers, 11 nondancers) who had reached menarche at the time of data collection, and it is likely that there was not sufficient power to produce a statistically significant relation. However, it is important to acknowledge that of the 10 participants who tested positive for scoliosis, 8 had not yet reached menarche; therefore, they were not skeletally mature, leaving them at higher risk of curvature progression.[13] This provides further justification for screening in this population because there is considerable risk of progression.[1,13]

A low BMI has also been associated with increased prevalence of scoliosis,[29,32,33] which is common in ballet dancers (50%) compared with nondancers, and may also contribute to the high prevalence of scoliosis in dancers.[34] BMI did not appear to influence the presence of scoliosis in this sample. However, this is unsurprising given that most of the dancers were classified as a healthy weight, giving little range in which to demonstrate a significant relation (see table 1).

Current evidence suggesting a high prevalence of scoliosis in dancing populations compared with controls focuses on professional or preprofessional dancers in intensive company programs with full-time training regimens of up to 50 hours of structured training per week.[16,17,30] Little research has been undertaken in programs with the less intensive schedule of younger dancers; therefore, it is unknown if the number of hours of dance training has any influence on the prevalence of scoliosis in dancers. Our study did not show that a higher number of hours of dance classes per week was related to a higher rate of scoliosis in adolescent dancers. For hours of dance practice, however, there was a trend indicating that prevalence of scoliosis increased with higher hours of unsupervised dance practice per week. However, given the lack of previous research into young dancers and our cross-sectional study design, it is difficult to accurately determine the mechanism behind this. It is possibly caused by the self-selection of dance as a serious sport by participants who possess characteristics that are desired in dance and that are associated with scoliosis (hypermobility, low BMI, delayed menarche); these individuals participate in more hours of dance practice than dancers who do not possess these characteristics.

Study limitations

Our cross-sectional study, although clearly demonstrating a high prevalence (30%) of scoliosis in adolescent dancers, could not determine a relation between scoliosis and the physical characteristics identified as predictors of scoliosis in previous dancer studies. A sample size calculation was performed for the primary outcome measure of determining the prevalence of scoliosis in adolescent dancer and nondancer groups prior to the study, and sufficient participants were recruited. However, because the secondary research question focused on the relations between specific characteristics found in the ballet dancers and AIS, only the ballet dancer group was included in analysis. It is likely that this smaller number (n=30) meant there was not enough power in the study to detect the relations reported in previous studies.

Future research could aim to ascertain the relation between scoliosis and hypermobility, delayed menarche, and BMI in young

Table 2 Association between presence of scoliosis and Beighton score, age of menarche, BMI, hours of dance classes per week, and hours of dance practice per week within the dancer group (n=30)

Variables	Wald Test	Significance	OR Exp (B)	95% CI for Exp (B)
Beighton score	1.300	.25	1.23	.86–1.75
Age of menarche (n=9)	0.005	.94	1.05	.30–3.65
BMI	0.750	.39	0.86	.62–1.20
No. of class hours	0.060	.81	0.95	.64–1.42
No. of practice hours	3.700	.06	2.16	.99–4.72

Abbreviations: CI, confidence interval; Exp (B), exponentiation of B coefficient; OR, odds ratio.

dancers using a larger sample. Given the multifactorial nature of AIS, this may be useful at more accurately assessing the relation of physical factors with AIS development.

Conclusions

This study has found a high prevalence of AIS in adolescent ballet dancers similar to the prevalence of scoliosis reported in adult ballet dancers. Given that treatment outcomes improve with earlier detection, benefit would be gained from implementing formal screening in dance schools and improving education of dance teachers and parents of dance students regarding the high rate of scoliosis in dancers and simple scoliosis screening methods.[8] Earlier detection may allow treatment to commence sooner, reducing the likelihood of surgery and complications (eg, pain, reduced range of motion, pulmonary compromise) and maximizing outcomes for the dancer in terms of health, function, and career.

Suppliers

a. Orthopaedic Systems Baseline Scoliometer 5280; 1897 National Ave, Hayward, CA 94545-1707
b. Seca 217 Stadiometer; 13601 Benson Ave, Chino, CA 91710
c. Taylor Digital Lithium Scales; Taylor Precision Products, 2311 W 22nd St, Oak Brook, IL 60523
d. SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, Il 60606.

Keywords

Cross-sectional studies; Dancing; Prevalence; Rehabilitation; Scoliosis

Corresponding author

Diana Hopper, PhD, GPO Box U1987, Perth, Western Australia 6845, Australia. *E-mail address:* D.Hopper@curtin.edu.au.

Acknowledgments

We thank Anne Smith, PhD, for her statistical expertise.

References

1. Weinstein SL, Dolan LA, Cheng JC, Danielsson A, Morcuende JA. Adolescent idiopathic scoliosis. Lancet 2008;371:1527-37.
2. Asher M, Burton D. Adolescent idiopathic scoliosis: natural history and long term treatment effects. Scoliosis 2006;1:1748-61.
3. Konieczny MR, Husseyin S, Krauspe R. Epidemiology of adolescent idiopathic scoliosis. J Child Orthop 2012;7:3-9.
4. Scoliosis. Perth (Western Australia): Child and Adolescent Health Service, Dept of Health, Government of Western Australia; 2011.
5. Shannon TML. Dynamic surface topography and its application to the evaluation of adolescent idiopathic scoliosis. Oxford: Department of Computing, Oxford Brookes Univ; 2010.
6. Freidel K, Petermann F, Reichel D, Steiner A, Warschburger P, Weiss HR. Quality of life in women with idiopathic scoliosis. Spine (Phila Pa 1976) 2002;27:E87-91.
7. Leong JC, Lu WW, Luk KD, Karlberg KM. Kinematics of the chest cage and spine during breathing in healthy individuals and in patients with adolescent idiopathic scoliosis. Spine (Phila Pa 1976) 1999;24:1310-5.
8. McCarthy RE. Prevention of the complications of scoliosis by early detection. Clin Orthop Relat Res 1987;(222):73-8.
9. Burwell RG, Dangerfield PH. The NOTOM hypothesis for idiopathic scoliosis: is it nullified by the delayed puberty of female rhythmic gymnasts and ballet dancers with scoliosis? Stud Health Technol Inform 2002;91:12-4.
10. Tanchev PI, Dzherov AD, Parushev AD, Dikov DM, Todorov MB. Scoliosis in rhythmic gymnasts. Spine (Phila Pa 1976) 2000;25:1367-72.
11. Warren M, Gunn B, Hamilton L, Warren LF, Hamilton W. Dance anatomy and kinesiology: principles and exercises for improving technique and avoiding common injuries. Champaign: Human Kinetics; 2007.
12. Good CR. The genetic basis of adolescent idiopathic scoliosis. J Spinal Res Found 2009;4:13-7.
13. Reamy BV, Slakey JB. Adolescent idiopathic scoliosis: review and current concepts. Am Fam Phys 2001;64:111-7.
14. Ogilvie J. Adolescent idiopathic scoliosis and genetic testing. Curr Opin Pediatr 2010;22:67-70.
15. Burwell RG, Aujla RK, Grevitt MP, et al. Pathogenesis of adolescent idiopathic scoliosis in girls - a double neuro-osseous theory involving disharmony between two nervous systems, somatic and autonomic expressed in the spine and trunk: possible dependency on sympathetic nervous system and hormones with implications for medical therapy. Scoliosis 2009;4:24.
16. Hamilton W, Hamilton L, Marshall P, Molnar M. A profile of the musculoskeletal characteristics of elite professional ballet dancers. Am J Sports Med 1992;20:267-72.
17. Kadel NJ, Donaldson-Fletcher EA, Gerberg LF, Micheli LJ. Anthropometric measurements of young ballet dancers: examining body composition, puberty, flexibility, and joint range of motion in comparison with non-dancer controls. J Dance Med Sci 2005;9:84-90.
18. Bunnell W. An objective criterion for scoliosis screening. J Hand Surg [Am] 1984;66:1381-7.
19. Amendt LE, Ause-Ellias KL, Eybers JL, Wadsworth CT, Nielsen DH, Weinstein SL. Validity and reliability testing of the scoliometer. Phys Ther 1990;70:108-16.
20. Coelho DM, Bonagamba GH, Oliveira AS. Scoliometer measurements of patients with idiopathic scoliosis. Braz J Phys Ther 2013;17:179-84.
21. Murray KJ. Hypermobility disorders in children and adolescents. Best Pract Res Clin Rheumatol 2006;20:329-51.
22. Smits-Engelsman B, Klerks M, Kirby A. Beighton score: a valid measure for generalised hypermobility in children. J Pediatr 2011;158:119-23.
23. Centers for Disease Control and Prevention. Children's BMI tool for schools - assessing your weight. 2011. Available at: http://www.cdc.gov/healthyweight/assessing/bmi/childrens_bmi/tool_for_schools.html. Accessed April 18, 2012.
24. Norton K, Olds T. Anthropometrica. 1st ed. Sydney: UNSW Pr; 1996.
25. Liederbach M, Spivak J, Rose D. Scoliosis in dancers: a method of assessment in quick-screen settings. J Dance Med Sci 1997;1:107-12.
26. Binns M. Joint laxity in idiopathic scoliosis. J Hand Surg [Br] 1988;70:420-2.
27. Czaprowski D, Kotwicki T, Pawłowska P, Stoliński L. Joint hypermobility in children with idiopathic scoliosis: SOSORT award 2011 winner. Scoliosis 2011;6:22.
28. Day H, Koutedakis Y, Wyon M. Hypermobility and dance: a review. Int J Sports Med 2011;37:485-9.
29. Grivas TB, Koukos K, Koukou UI, Maziotou C, Polyzois BD. The incidence of idiopathic scoliosis in Greece - analysis of domestic school screening programs. Scoliosis 2002;91:71-5.
30. Warren MP, Brooks-Gunn J, Hamilton LH, Warren LF, Hamilton WG. Scoliosis and fractures in young ballet dancers. Relation to delayed menarche and secondary amenorrhea. N Engl J Med 1986;314:1348-53.

31. Herrera-Soto J, Crawford A. Idiopathic scoliosis in children and adolescents: diagnosis and treatment options. Ped Health 2008;2: 89-98.
32. Dangerfield PH, Davey RC, Chockalingam N, Cochrane T, Dorgan JC. Body composition in females with adolescent idiopathic scoliosis (AIS). J Hand Surg [Br] 2006;88:230-1.
33. Y1 Qui, Qiu XS, Sun X, et al. [Body mass index in girls with adolescent idiopathic scoliosis] [Chinese]. Zhonghua Wai Ke Za Zhi 2008;46:588-91.
34. Stotik E, Srdic B, Barak O. Body mass index, body fat mass and the occurence of amenorrhea in ballet dancers. Gynecol Endocrinol 2005; 20:195-9.