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# The effect of a corrective functional exercise program on postural thoracic kyphosis in teenagers: a randomized controlled trial

**Qiang Feng[1], Mei Wang[1], Yanfeng Zhang[1] and Yu Zhou[2]**


## Abstract

**Objective:** To investigate the effects of a corrective functional exercise program on postural thoracic kyphosis in teenagers in China.

**Design:** A single-blind randomized controlled trial including students with a thoracic kyphosis angle (TKA) >40° measured using the SpinalMouse.

**Setting:** China Institute of Sport Science and three middle schools in Beijing, China.

**Subjects:** A total of 181 subjects were included in this trial; of these, 164 subjects were included in the analyses (intervention group, $n = 81$; control group, $n = 83$).

**Intervention:** The intervention group received a functional exercise program designed to correct postural thoracic kyphosis, and the control group received an exercise program designed in accordance with the state-regulated curriculum.

**Main measures:** The primary outcome variable was TKA. Secondary outcome variables were lumbar lordosis angle (LLA), sacral angle (SA), and incline angle (INA) measured in the upright position; thoracic, lumbar, and sacral spine range of motion (ROM) and INA ROM (change in center of gravity) measured in the forward bending and extended positions; and changes in TKA, LLA, SA, and INA measured during the Matthiass test.

**Results:** There were significant differences in pretest and posttest TKA in both groups (intervention group: pretest 47.09 ± 5.45, posttest 38.31 ± 9.18, $P < 0.0001$; control group: pretest 47.47 ± 6.06, posttest 43.59 ± 7.49, $P < 0.0001$). After adjustment for gender and pretest values, there were significant differences in posttest TKA, change in SA, and thoracic ROM in the intervention group compared to the control group ($P < 0.05$).

**Conclusion:** The corrective functional exercise program designed for this study improved exaggerated thoracic kyphosis in teenagers.



## Keywords

Functional exercise program, teenager, abnormality of the sagittal posterior process of thoracic vertebrae

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[1]China Institute of Sport Science, Beijing, China
[2]National Institute of Education Sciences, Beijing, China

**Corresponding author:**
Qiang Feng, China Institute of Sport Science, No. 11, Tiyuguan Road, Dongcheng District, Beijing 100061, China.
Email: fengqiang@ciss.cn

## Introduction

Postural hyperkyphosis is a common spinal curvature disorder[1,2] caused when high external loads are applied to the spine of individuals in the upright stance who have poor overall muscle strength.[3] Hyperkyphosis is associated with rapid degeneration of the spinal column as well as disorders of the thoracic and cervical vertebrae,[4] including cervical lordosis, which can result in upper crossed syndrome.[5] In rapidly growing teenagers, abnormal flexion of the spine impedes development of the viscera, and exaggerated thoracic kyphosis is associated with altered respiratory function.[6] In addition, hyperkyphosis can affect a teenager's posture and appearance and may therefore impact their physical and psychological health.

The normal range of thoracic kyphosis in teenagers is 20°–40°, and a hyperkyphosis diagnosis is considered beyond 45°.[7,8] Accumulating evidence suggests that individuals with exaggerated kyphosis often present with deformities in the sagittal plane.[9–11] In teenagers, sagittal misalignment can result from sitting for extended periods of time as well as poor posture while sitting and standing.[12]

Corrective exercise programs for hyperkyphosis in adults are designed according to Kendall's theory, which involves stretching and strengthening of muscles in the affected area.[13] However, a lack of controlled studies testing the effectiveness of Kendall's theory has led researchers to question the utility of corrective exercise programs for postural hyperkyphosis.[14] Furthermore, most currently available corrective exercise programs for hyperkyphosis are limited, as evidence indicating that they achieve a clinically important improvement in the thoracic kyphosis angle (TKA) is scarce. This may be because the programs are short and rely on self-training, and qualitative methods are used to measure the TKA. In particular, these corrective exercise programs are targeted to the thoracic vertebrae, which is in contrast to the holistic approach that is increasingly favored for the treatment of exaggerated thoracic kyphosis.[15–17]

Studies on corrective exercise programs for exaggerated thoracic kyphosis due to deformities in the sagittal plane in teenagers are scarce. The objective of this randomized controlled study was to compare the effects of a corrective functional exercise program and an exercise program designed according to the state-regulated curriculum on postural thoracic kyphosis in teenagers with sagittal misalignment. We hypothesized that the corrective functional exercise program would achieve a greater decrease in our primary outcome measure of TKA compared to the exercise program designed according to the state-regulated curriculum.

## Methods

### Study design

This study is a single-blind randomized controlled trial (Registration # ChiCTR-INR-16008860). Instructors were blinded to the clinical characteristics of the study participants. The study was conducted according to China Institute of Sport Science guidelines and was approved by the ethics committee of our institution (No. 16-32). Written informed consent was obtained from each study subject and their parents.

### Participants

Students from three middle schools in Beijing City, China (Beijing No. 156 Middle School, West City Experimental Middle School, and Beijing No. 35 School), were chosen for this study. Study subjects were recruited during a period of one month (1 September 2015 to 30 September 2015). The inclusion criterion was TKA >40°measured using the SpinalMouse system (Idiag, Fehraltorf, Switzerland). The SpinalMouse is a non-invasive test of spinal morphology and spinal function. It uses a surface-based procedure to measure the range of motion (ROM) and intersegmental angles of the sagittal spine. The SpinalMouse has high accuracy when testing spinal morphology and function in the sagittal plane.[18–20] It is sufficiently reliable and valid compared to X-ray.[21] Intraclass coefficients (ICCs) for curvature measurement with the SpinalMouse are 0.92–0.95,[18] and intra- and inter-rater ICCs range from 0.82 to 0.83 and 0.81 to 0.86,[22] respectively.

Exclusion criteria were as follows: structural thoracic kyphosis, defined as thoracic kyphosis that did not partially or completely disappear during prone extension, as assessed by a physical therapist; medical history of spinal fracture, spinal surgery, shoulder joint injury, pelvic injury, or other spinal diseases; presence of scoliosis on Adam's forward bend test; spinal kyphosis due to visible thoracic deformity; students undergoing professional sports training; and students with medical conditions that restricted activity.

Students who met the inclusion criterion and none of the exclusion criteria were randomly assigned to an intervention group or a control group by simple random sampling using random number generation. Study subjects were followed-up from 1 October 2015 to 15 December 2015.

## Spinal shape and motility measurements

Students' spinal shape and motility was evaluated before the intervention (pretest) and during week 9, after the intervention (posttest). Pretest and posttest, spinal shape, and motility were evaluated with the SpinalMouse system. During the procedure, subjects stood on the floor without coats or shoes. The spinal process at vertebra C7 and the top of the anal crease at S3 were marked with a pen. Spinal curvature and pelvic tilt were measured for each subject in several positions:

*Upright position.* Study subjects were instructed to stand upright in a casual position, feet shoulder-width apart bearing equal weight, arms by their sides, and looking straight ahead.

*Forward bending position.* Study subjects were instructed to stand with their feet shoulder-width apart and to flex the torso forward while keeping the legs straight and allowing the arms to fall naturally.

*Extended position.* Study subjects were instructed to stand with their feet shoulder-width apart bearing equal weight, arms by their sides or supported by the hips, looking straight ahead. Subjects were asked to stretch the torso backward as far as possible.

*Matthiass test.* Study subjects were instructed to stand with their feet shoulder-width apart, looking straight ahead. When asked, subjects flexed their arms to 90°.[23] Spinal curvature and pelvic tilt were measured. The subject was instructed to retain this posture for 30 seconds, at which time a second spinal curvature and pelvic tilt measurement was made.

## Functional exercise program

All study subjects received two 15–20 minute exercise sessions each week for eight weeks during their physical education classes at high school. Total duration of the physical education classes was 20 minutes. The time spent on the exercise sessions during the physical education classes was determined by discussions with the physical education teachers and the administration leaders of the schools.

The intervention group took part in a functional exercise program designed to correct postural thoracic kyphosis, which incorporated specific exercises for the cervical, thoracic, and lumbar spine as well as the pelvis (Appendix A, supplementary data). The exercises, repetitions, and hold time were selected based on the authors' clinical experience. Physical education teachers at the participating schools were provided training to ensure consistent application of the functional exercise program. The functional exercise program aimed to recover ROM in the cervical, thoracic, and lumbar spine and to improve subjects' muscle strength and proprioception.

The control group received an exercise program designed according to the state-regulated curriculum, which included abdominal curls, pushups with the toes or knees, a 50 m run, and squats (Appendix B, supplementary data).

## Statistical analysis

Statistical analyses were conducted using SPSS v19.0 software (SPSS, Inc., Chicago, IL). Study sample size was based on the assumption that a 5° change in TKA is a clinically important difference. Assuming an SD of 2°, and using the two-tailed hypothesis, $\alpha = 0.05$, and 80% power, a sample size of ≥51 per group was required for this study.

The primary outcome variable was TKA. Secondary outcome variables were lumbar lordosis angle (LLA), sacral angle, and incline angle (INA) measured in the upright position; thoracic, lumbar, and sacral spine ROM and INA ROM (change in center of gravity) measured in the forward bending and extended positions; and changes in TKA, LLA, sacral angle, and INA measured during the Matthiass test.

Results are presented as mean ± SD. The Kolmogorov–Smirnov test was used to determine if variables were normally distributed. Differences in pretest and posttest values in the intervention and control groups were compared with the Student's *t*-test for normally distributed data and Wilcoxon test (Mann–Whitney *U* test) for variables that were not normally distributed. Where significant differences in pretest and posttest values were found, covariance analysis was used to adjust for gender and pretest value. Independent *t*-test was applied to evaluate between-group differences when pretest value was identified as an extraneous variable.

## Results

A total of 212 subjects were eligible for this study. In all, 181 subjects met all the inclusion criteria and none of the exclusion criteria. Of these, 90 subjects were randomized to the intervention group and 91 were randomized to the control group; 81 subjects in the intervention group and 83 subjects in the control group were finally included in the analyses (Figure 1). Baseline characteristics of the study subjects are shown in Table 1; there were no significant between-group differences.

Tables 2 and 3 show the primary and secondary outcome variables in the intervention and control groups before and after the exercise programs. There was a significant difference in pretest and posttest TKA in both the intervention and control groups (intervention group: pretest 47.09 ± 5.45, posttest 38.31 ± 9.18, $P < 0.0001$; control group: pretest 47.47 ± 6.06, posttest 43.59 ± 7.49, $P < 0.0001$).

There were also significant differences in pretest and posttest INA (intervention group: pretest 3.15 ± 5.04, posttest −0.16 ± 4.40, $P < 0.0001$; control group: pretest 2.41 ± 4.64, posttest 0.31 ± 6.53, $P = 0.01$) and change in INA (intervention group: pretest−0.69 ± 3.10, posttest −2.20 ± 3.09, $P = 0.002$; control group: pretest −2.65 ± 3.13, posttest −1.89 ± 3.42, $P = 0.04$) in both the intervention and control groups. There were significant differences in pretest and posttest thoracic ROM (intervention group: pretest 14.56 ± 17.92, posttest 22.53 ± 19.19, $P = 0.003$) and change in sacral angle (intervention group: pretest 0.10 ± 4.81, posttest −1.89 ± 3.55, $P = 0.004$) in the intervention group.

Tables 4 and 5 show between-group differences. After adjustment for gender and pretest values, there were significant decreases in posttest TKA and change in sacral angle ($P < 0.004$) in the intervention group compared to control (Table 4). Furthermore, after adjustment for pretest values, there was a significant difference in the change in thoracic ROM in the intervention group compared to control ($P < 0.05$; Table 5).

## Discussion

This study investigated the effects of a corrective functional exercise program on postural thoracic kyphosis in teenagers with sagittal misalignment. The corrective functional exercise program achieved a clinically significant decrease in TKA (approximately 9°), as well as changes in the sacral angle and thoracic ROM. Furthermore, the posttest TKA and change in sacral angle was significantly different following the corrective functional exercise program compared to control. The corrective exercise program used a holistic approach that considered muscle flexibility and strength and proprioception along the length of the spine. Interestingly, there was also a decrease in TKA in study subjects participating in the control exercise program. Although the decrease was not as great as in study subjects participating in the corrective functional exercise program, this finding emphasizes the importance of general exercise for spine health in teenagers.

The findings from this study are in accordance with previous reports in adults. An in-home exercise program targeting Erector Spine strength, cervical retraction, interscapular muscle strengthening, and pectoral stretching achieved a statistically but not clinically significant 3° decrease in TKA after 13 weeks.[24] In adult males, an intervention that involves stretching and flexion of the thoracic vertebrae plus muscle strength training alleviated pain and decreased thoracic kyphosis by 7°.[25] In females

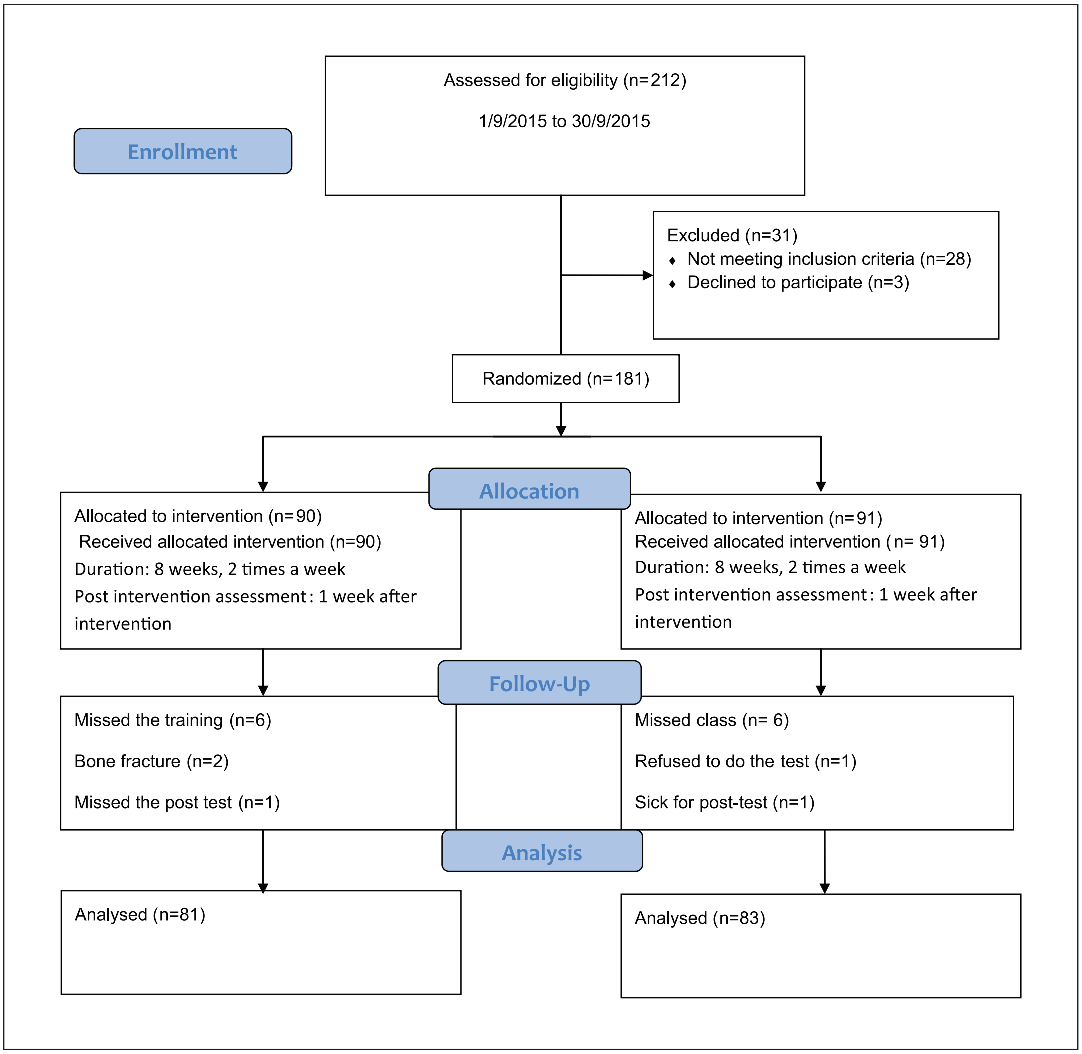


**Figure 1.** CONSORT 2010 Flow Diagram.

aged 50–59 years, a long-term intervention that included stretching the upper and lower back, shoulders, and neck reduced the progression of thoracic kyphosis; however, compliance with the program was low.[26]

An effectively designed corrective exercise program should consider muscle flexibility as well as strength and proprioception along the length of the spine. Adherence to this type of corrective program will restore the spine to its normal position and movement and allow the body to automatically maintain the orientation of the spine during static and dynamic loads. This study is among the first to design and implement a corrective functional exercise program for postural thoracic kyphosis in teenagers with sagittal misalignment.

The corrective functional exercise program had a significant effect on sacral angle compared to the control exercise program, as shown by the Matthiass test, which assesses an individual's capacity to maintain their posture against an external load.[27] A large sacral angle indicates that the pelvis is tilting forward and is a risk factor for spinal disorders.[28,29] In this study, the sacral angle among subjects in the

**Table 1.** Baseline demographics of study subjects.

| | *N* | Gender | Age | Height | Weight | BMI |
|---|---|---|---|---|---|---|
| Intervention (*n* = 90) | 51 | Male (56.7%) | 14.2 ± 1.43 | 171.9 ± 7.80 | 64.4 ± 16.03 | 21.6 ± 4.35 |
| | 39 | Female (43.3%) | 14.0 ± 1.52 | 163.4 ± 5.71 | 56.6 ± 14.25 | 21.1 ± 4.54 |
| Control (*n* = 91) | 53 | Male (58.2%) | 13.5 ± 1.47 | 171.0 ± 8.44 | 64.7 ± 15.01 | 21.9 ± 4.04 |
| | 38 | Female (41.8%) | 13.6 ± 1.54 | 162.5 ± 7.01 | 53.4 ± 9.40 | 20.2 ± 3.00 |

BMI: body mass index.

**Table 2.** Primary and secondary outcomes (paired-sample *t*-test).

| | *N* | Pretest | Posttest | Within-group difference | *T* value | 95% CI | *P* |
|---|---|---|---|---|---|---|---|
| *Primary outcome* | | | | | | | |
| Thoracic kyphosis angle | | | | | | | |
| Intervention | 81 | 47.09 ± 5.45 | 38.31 ± 9.18 | 3.81 ± 3.67 | 88.74 | 66.78 to 10.78 | **<0.0001** |
| Control group | 83 | 47.47 ± 5.80 | 43.59 ± 7.49 | 4.08 ± 4.28 | −4.9 | −2.30 to 5.46 | **<0.0001** |
| *Secondary outcomes* | | | | | | | |
| Sacral angle | | | | | | | |
| Intervention | 81 | 10.32 ± 7.75 | 10.75 ± 6.89 | 2.73 ± 2.58 | −0.45 | −2.35 to 1.48 | 0.66 |
| Control | 83 | 12.93 ± 6.43 | 11.57 ± 7.38 | 2.30 ± 2.72 | 1.67 | −0.26 to 2.98 | 0.099 |
| Lumbar lordosis angle | | | | | | | |
| Intervention | 81 | 22.07 ± 8.97 | 23.69 ± 8.47 | 3.30 ± 3.32 | 1.74 | −0.23 to 3.47 | 0.09 |
| Control | 83 | 26.23 ± 6.38 | 25.63 ± 8.31 | 2.78 ± 2.55 | −0.71 | 2.28 to 1.08 | 0.48 |
| Incline angle | | | | | | | |
| Intervention | 81 | 3.15 ± 5.04 | −0.16 ± 4.40 | 2.40 ± 2.07 | 5.15 | 2.03 to 4.59 | **<0.0001** |
| Control | 83 | 2.41 ± 4.64 | 0.31 ± 6.53 | 2.20 ± 2.39 | 2.56 | 0.47 to 3.72 | **0.01** |
| Sacral ROM | | | | | | | |
| Intervention | 81 | 68.46 ± 23.36 | 65.44 ± 25.86 | 17.43 ± 14.73 | 1.19 | −2.01 to 8.03 | 0.24 |
| Control | 83 | 72.13 ± 23.51 | 71.39 ± 22.63 | 17.52 ± 16.66 | 0.28 | 4.55 to 6.04 | 0.78 |
| Thoracic ROM | | | | | | | |
| Intervention | 81 | 14.56 ± 17.92 | 22.53 ± 19.19 | 19.53 ± 15.09 | −3.06 | −13.16 to 2.80 | **0.003** |
| Control | 83 | 16.77 ± 16.60 | 17.95 ± 20.90 | 14.77 ± 12.92 | −0.55 | −5.47 to 3.11 | 0.59 |
| Lumbar ROM | | | | | | | |
| Intervention | 81 | 66.88 ± 21.69 | 69.38 ± 17.27 | 15.28 ± 13.16 | −1.13 | −6.94 to 1.93 | 0.27 |
| Control | 83 | 75.88 ± 16.79 | 72.13 ± 17.60 | 12.92 ± 11.07 | 1.87 | −0.22 to 7.71 | 0.06 |
| Incline angle ROM | | | | | | | |
| Intervention | 81 | 129.52 ± 19.47 | 130.16 ± 19.65 | 15.46 ± 13.88 | −0.28 | −5.25 to 3.97 | 0.78 |
| Control | 83 | 141.08 ± 18.34 | 138.98 ± 17.07 | 13.22 ± 13.45 | 1.022 | −2.00 to 6.21 | 0.31 |
| Change in sacral angle | | | | | | | |
| Intervention | 81 | 0.10 ± 4.81 | −1.89 ± 3.55 | 2.73 ± 2.58 | 2.93 | 0.64 to 3.34 | **0.004** |
| Control | 83 | −0.88 ± 4.33 | −0.27 ± 3.70 | 2.30 ± 2.72 | −1.084 | −1.74 to 0.51 | 0.28 |
| Change in lumbar lordosis angle | | | | | | | |
| Intervention | 81 | −1.09 ± 5.69 | −0.68 ± 3.68 | 3.30 ± 3.32 | −0.60 | −1.76 to 1.00 | 0.55 |
| Control | 83 | −1.70 ± 4.92 | −2.05 ± 4.78 | 2.78 ± 2.55 | 0.53 | −0.98 to 1.67 | 0.6 |

CI: confidence interval; ROM: range of motion.
Bold values indicate $p<0.05$.

**Table 3.** Secondary outcomes (Wilcoxon test).

| | *N* | Pretest | Posttest | Within-group difference | *T* value | *P* |
|---|---|---|---|---|---|---|
| *Secondary outcomes* | | | | | | |
| Change in thoracic kyphosis angle | | | | | | |
| Intervention | 81 | −0.51 ± 5.45 | −0.07 ± 5.04 | –0.31 ± 5.30 | −0.28 | 0.78 |
| Control | 83 | −1.83 ± 5.37 | −1.36 ± 7.03 | 1.02 ± 5.85 | −0.35 | 0.72 |
| Change in incline angle | | | | | | |
| Intervention | 81 | −0.69 ± 3.10 | −2.20 ± 3.09 | 0.62 ± 3.12 | −3.04 | 0.002 |
| Control | 83 | −2.65 ± 3.13 | −1.89 ± 3.42 | −0.16 ± 3.26 | −2.09 | 0.04 |

**Table 4.** Between-group differences (covariance analysis).

| Variable | Mean square | *F* | *P* |
|---|---|---|---|
| Thoracic kyphosis angle | 1049.73 | 17.19 | **<0.001** |
| Incline angle | 15.55 | 0.511 | 0.476 |
| Change in sacral angle | 114.625 | 8.661 | **0.004** |
| Change in incline angle | 14.452 | 1.456 | 0.229 |

Bold values indicate $p<0.05$.

**Table 5.** Between-group differences in thoracic kyphosis angle (independent-sample *t*-test).

| | *N* | Difference | *T* | 95% CI | *P* |
|---|---|---|---|---|---|
| Intervention | 81 | 7.98 ± 23.44 | 2.013 | 0.13–13.46 | **0.046** |
| Control | 83 | 1.18 ± 19.66 | – | – | **–** |

CI: confidence interval.
Bold values indicate $p<0.05$.

intervention group decreased, which indicates that the corrective functional exercise program enabled study subjects to maintain their sacral angle and posture under a load. This may be the result of the stability-based training component of the corrective functional exercise program, which is targeted at the muscles of the lower back and hips.

After the corrective functional exercise program, study subjects were able to accommodate an external load and maintain the shape of their sacrum and pelvis through the strength of the muscles in the core. However, these results should be interpreted with caution. Study subjects were instructed to keep their knees straight during the Matthiass test; therefore, due to the anatomical relationship between the sacrum and pelvis, values of the sacral angle measured with the SpinalMouse system could reflect the position and ROM of the pelvis rather than the sacral angle.

In addition to the improvements in TKA and sacral angle, the corrective functional exercise program had a significant effect on thoracic ROM compared to the control exercise program. The corrective functional exercise program included two exercises that were expected to improve thoracic ROM, including the thoracic spine extension ROM and the thoracic spine rotation ROM. Improvements in thoracic ROM facilitate recovery of the normal curvature of the thoracic spine. However, it is currently unclear whether the improvement in TKA after the corrective functional exercise program implemented in this study was directly related to the changes in thoracic ROM.

The Matthiass test showed improvements in the INA in both the intervention and control groups. The INA represents the angle between a line connecting T1 and S1 and the vertical. Pretest, study subjects had a tendency to lean forward; this was corrected by the functional exercise program and the control exercise program. A forward posture loads weight onto the extensor muscle of the spine and can have a negative effect on spinal health. Further research is required to elucidate the association between a forward posture and thoracic kyphosis.

Recovery of proprioception is important for correcting posture problems and maintaining good posture. Therefore, corrective exercise programs should include components targeted at restoring proprioception. Evidence suggests that dynamic movements improve proprioception more than static movements.[30] Therefore, in this study, most of the movements included in the corrective functional exercise program were designed to be dynamic. Study subjects were taught how to stand correctly, and the importance of maintaining correct posture was emphasized throughout the program thereby reinforcing proprioception. We propose this is a key element of our corrective functional exercise program.

This study had several strengths. First, it was a single-blind randomized controlled trial. Second, the intervention and control exercise programs were implemented by physical education teachers in schools, and all participating schools included students in the intervention and control groups. Third, covariance analysis was used to correct outcome measures for pretest values. This minimized bias and ensured the validity and reliability of the data.

However, the study also has some limitations. First, the SpinalMouse system was used to measure spinal curvature. Although a recent systematic review confirmed the reliability of the SpinalMouse as a non-invasive measure for thoracic kyphosis, X-ray provides the most accurate measure of spinal curvature, and values obtained from the SpinalMouse may be smaller than those measured by X-ray,[18,19,21] particularly in the sagittal spine.[31] Second, we propose that the corrective functional exercise program improved muscle strength and enhanced proprioception in the study population; however, quantitative measurement and analysis of proprioception are challenging.[32] Future studies should focus on developing a reliable test for the evaluation of proprioception, which may contribute to understanding the mechanisms of change. Third, the corrective functional exercise program was designed to improve cervical, thoracic, and lumbar ROM and associated muscle strength. However, there was no obvious change in lumbar lordosis and lumbar ROM in the intervention group. The duration of the corrective functional exercise program may have been too short to affect lumbar lordosis as evidence suggests the lumbar spine becomes functionally and mechanically deconditioned very quickly during sedentary behavior,[33,34] and these changes are long-lasting and may be challenging to reverse. In addition, the cat stretch exercise, which was developed to address lumbar ROM, was difficult to perform. More effective exercises for lumbar lordosis and ROM should be included in a future iteration of the corrective functional exercise program.

In conclusion, the corrective functional exercise program designed for this study improved exaggerated thoracic kyphosis in teenagers. The exercise program also improved thoracic ROM, function of the muscles around the pelvis, and capability to accommodate weight loaded onto the upper and the lower body. This program could be incorporated into high school physical education curricula in China to promote spine health in teenagers.

## Clinical Messages

- A corrective functional exercise program that focuses on the entire spine has a positive effect on thoracic kyphosis in teenagers.
- This corrective functional exercise program is feasible to incorporate in high school physical educational classes and could promote the spine health in teenagers.

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## Declaration of Conflicting Interests

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