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The influence of an in-home based therapeutic exercise program on thoracic kyphosis angles

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Abstract. *Objective:* Altered postural presentations have been associated with a variety of musculoskeletal disorders. Therapeutic exercise interventions are often utilized to manage patients with increased thoracic kyphosis or "round shoulders," yet few controlled studies have evaluated their efficacy.
Design: A prospective, randomized, controlled design was used to evaluate the influence of a home-based exercise regimen on these postural variances. Seventy-one patients with real or perceived concerns about their thoracic posture completed the 13-week study. Patients with 23–80° of thoracic kyphosis entered the study. Pre- and post-intervention flexicurve measurements of thoracic kyphosis were made. Patients were randomly assigned to an exercise ($n = 32$) or control group ($n = 39$). A mixed design ANOVA tested main effects and interactions.
Results: A statistically significant ($p < 0.05$) interaction was found between group assignment and delta kyphosis values. Post-hoc analysis of the multiple comparisons produced a marginal p-value ($p = 0.0557$). Mean delta kyphosis values were (+) 0.5° (±7.0°) for the control group and (−) 3.0° (±6.1°) for the experimental group.
Conclusions: This 13-week home exercise program targeting modification of thoracic kyphosis angles had a statistically significant impact. However, post-hoc statistical analyses and clinical implications are marginal.

Keywords: Evidence-based practice, outcome measures, postural relationships

1. Introduction

1.1. Influence of exercise on posture

The normal range of thoracic kyphosis is 20–45° [6, 13–15,20–22]. Excessive kyphosis (> 45°) is an etiological factor of, or significant impairment in, upper quarter pathologies ranging from shoulder pain to spinal compression fractures [3,9,12,17,20,26]. Physical therapists routinely use therapeutic exercises to manage patients with hyper-kyphosis. However, the quality of evidence that supports effective therapeutic exercise interventions for this postural abnormality is lacking. In 2001, Hrysomallis and Goodman [10] published a literature review which evaluated the effect of exercise for the correction of postural abnormalities. The authors concluded that, "Based on the existing literature, it is inadvisable to strongly promote strengthening exercises to correct postural malalignments, such as abducted scapulae, excessive lumbar lordosis, scoliosis, or kyphosis." (p. 389). Poor methodology and/or the absence of a control group confounded the results of many of the studies they reviewed [10].

Itoi and Sinaki [11] evaluated the effect of a prone-lying spinal extension exercise on kyphosis angles and thoracic spinal extensor strength. The study was conducted over a two-year period of time on 60 patients with estrogen deficiency. The patients were 49–65 years old (mean = 59). Their range of kyphosis angles was 9.5–69.5° (mean = 34.1°). The experimental group ($n = 32$) showed no statistically significant improvement in the kyphosis angle, as compared to the control group ($n = 28$). This was in spite of the fact

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that both groups increased their back extensor strength, with the experimental group doing so to a greater extent ($p = 0.0036$). The patients trained their Erector Spinae with 30% of their maximum voluntary isometric contraction (MVIC) using a weighted backpack. The maximum load applied was 50 pounds. In a stratified analysis of their data, the authors reported a statistically significant ($p = 0.0016$) kyphosis angle improvement of $-2.8°$ ($\pm$ 4.2°) in their *strong* extensor spinae group compared to a worsening of the kyphosis angle of 1.8° ($\pm$ 5.3°) in their *weak* back extensor group.

1.2. Longitudinal monitoring of kyphosis angles

Monitoring kyphosis values over time is complicated by two factors. First, the gold standard for kyphosis measurements is the invasive Cobb angle technique. Second, the amount of normal kyphosis angle variability has not been established. A non-invasive instrument, the flexicurve, was selected as the measurement tool for this study. The flexicurve has demonstrated reliability and validity for kyphosis angle measurements [2, 8,15,27]. Lundon et al. [15] concluded that, "The attribute of the flexicurve to qualitatively evaluate posture permits design of a specific strategy for the purpose of postural retraining and for the longitudinal study of kyphotic curve change induced by disease progression or therapeutic intervention." (p. 1984).

Hart and Rose [8] used the flexicurve to measure flexed and extended lumbar spine angles and concluded that the instrument had good intratester reliability (ICC = 0.97) and validity. Obviously, full lumbar flexion values replicate measures of thoracic kyphosis in that both assess posterior convexity of the spine. The flexicurve's validity has been assessed by comparing the instrument's measures of sagittal spinal angles with radiographic measurements. Tillotson and Burton [27] compared radiographically measured angles of lumbar spine flexion to those taken with the flexicurve and found that the latter consistently produced measures within six degrees of the radiographic method.

1.3. Purpose of the study

The purpose of the present study was to evaluate the influence of home-based therapeutic exercises on patients with idiopathic postural kyphosis using methodology that reflects a common clinical practice model. Patients were given a single visit to the therapist and required to carry out the exercises at home. Previous studies have validated the efficacy of home exercise programs both in terms of patient compliance and desirable outcomes [7,23,25]. Seven exercises were selected to influence kyphosis angles. The exercises were selected on the basis of the lead author's 30 years of clinical physical therapy practice and a review of the literature.

2. Methods

2.1. Pilot study

The lead author established test-retest reliability with the flexicurve by measuring the kyphosis angles of 35 asymptomatic college students on two occasions, two weeks apart. A measurement error of 3.2° was calculated. The ICC value for those measures was 0.92 (95% CI = 0.84–0.96). This value reflects the intra- and interrater measures produced by Lundon et al. [15] (0.89−0.97, no CI reported).

2.2. Selection of participants

Seventy-five patients (24 males and 51 females) were referred to the study. The patients' age range was 21–63 years (mean = 39.8 $\pm$ 13.2). An adult population was chosen to minimize the influences of skeletal maturation. Patients were referred to the study if they were interested in improving their upper back posture. Persons with a range of normal and abnormal kyphosis values (23–80°) participated in the study. Those presenting with kyphosis angles above the normal range ($n = 31$; or 44%) had idiopathic, postural kyphosis, as described by Winter and Hall [29]. The authors included persons with a wide range of kyphosis angle measurements in order to evaluate the influence of the exercise program on patients across the spectrum of potential clinical presentations. This is consistent with the methods used by Itoi and Sinaki [11] where patients with as little as nine degrees of kyphosis were included.

2.3. Exclusion criteria

Patients were excluded from the study if they:

1. were outside the age range of 20–65 years,
2. had a medical prescription that specifically dictated therapeutic exercises for posture. Failure to exclude this patient would have resulted in an ethical dilemma of patients not receiving the appropriate exercises prescribed by the referring physician, if that patient was ultimately assigned to the control group.

3. had a Scoliometer^{TM} reading of greater than five degrees at the point of peak axial rotation on the forward bending test.
4. had a structural kyphosis, confirmed by radiographs.

2.4. Screening of participants

Following random assignment, patients were further screened by the lead investigator for limitations in range of motion that would interfere with their ability to perform the exercises. Patients were also screened for excessive axial trunk rotation, using the Scoliometer^{TM}. Amendt et al. [1] established the utility of this instrument for scoliosis screening. Since the exercises utilized in the present study were not designed to influence tri-planar thoracic curvatures, patients with potentially significant scoliosis were excluded from the study.

2.5. Kyphosis measurements

The flexicurve is a malleable, metal ruler covered with plastic that can be bent only in a single plane. Once bent, it retains its shape to conform to the patient's spine. Three consecutive thoracic kyphosis angle measures were made. The mean of these measurements served as the pre-participation kyphosis angle. Every kyphosis angle measurement followed the same protocol. The lead author first identified, through palpation, the spinous processes of T1 and T12 and marked them with a skin marker. The patient was asked to inhale and exhale without forcing out the breath. The flexicurve was carefully conformed to the thoracic spine (Fig. 1). The researcher noted the span of the curve using the flexicurve's ruler. This process was repeated three times. The lead author calculated the kyphosis angle from the three tracings. Figures 2 and 3 illustrate the method described by Hart and Rose [8], as well as the trigonometric calculation, used to determine the kyphosis angle in the current study.

2.6. Exercise protocol and instruction

A literature review produced few articles where exercises were prescribed specifically to influence postural changes in the adult thoracic spine. The seven exercises prescribed in the current study were a combination of strengthening, stretching, and self-mobilization activities (Appendix 1). The exercises targeting Erector Spinae strength were selected on the basis of evidence provided by Moffroid et al. [18]. The cervical retraction exercise was recommended by McKenzie [16] and Moore [19] for its postural realignment value. The interscapular muscle strengthening and pectoral stretching exercises were validated by Wang et al. [28] as a way to improve upper trunk posture and scapular stability. These authors reported a reduction of thoracic "anterior inclination" as a result of their six-week exercise program.

Fig. 1. Application of the flexicurve to the patient's back for kyphosis measurement.

The exercises in this study were carefully dosed by a research assistant. This licensed physical therapist has more than 20 years of clinical practice in primarily outpatient orthopedic settings. Her primary intent in teaching the exercises was accurate performance without discomfort.

The research assistant contacted the patients within 24 hours of his/her initial data collection session. The assistant determined the patient's group assignment by inquiring as to the number the patient rolled on the die. Patients assigned to the control group were told that they would be contacted in three months for a follow-up data collection session. No further contact with this group occurred until the follow-up appointment was established. Patients assigned to the experimental group were given an appointment with the research assistant in order to learn the exercises.

All seven exercises were prescribed with appropriate progressions defined for repetitions, resistance (in the case of the Theraband^{TM} (Hygenic Corporation, Akron OH) exercises), and hold times over the course of the 13-week training program. Two levels of band resistance were given to the patient at the training session; one appropriate to the patient's abilities at the initial session and a second band one resistance grade higher. Detailed written and pictorial descriptions (Ap-

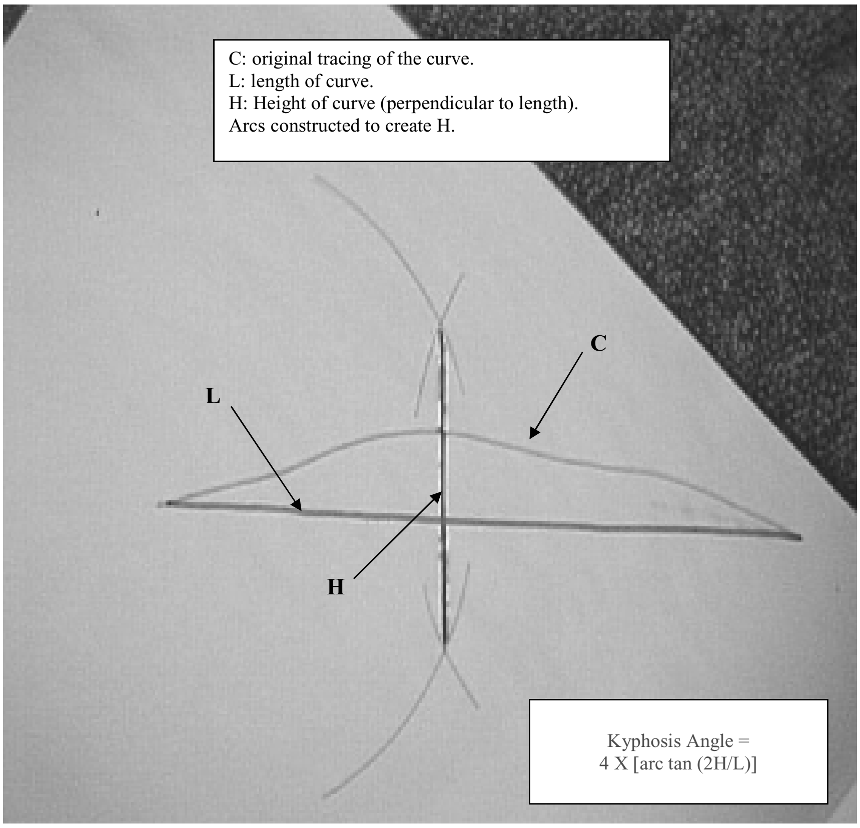


Fig. 2. An original tracing from the flexicurve (C) with height (H) and length (L) of the curve constructed.

pendix 1) were issued to the patients in order to optimize exercise performance.

All exercises were prescribed without modification to 17/32 (53%) of the patients in the experimental group. In two of the remaining fifteen patients, two of the exercises were modified to accommodate inabilities to assume the start or finish positions of the exercises. Thirteen patients had a single exercise modified for the same reason. These modifications (Appendix 2) reflect standard physical therapy practice. The exercises were carried out four days-per-week over the thirteen week interval in the patients' homes.

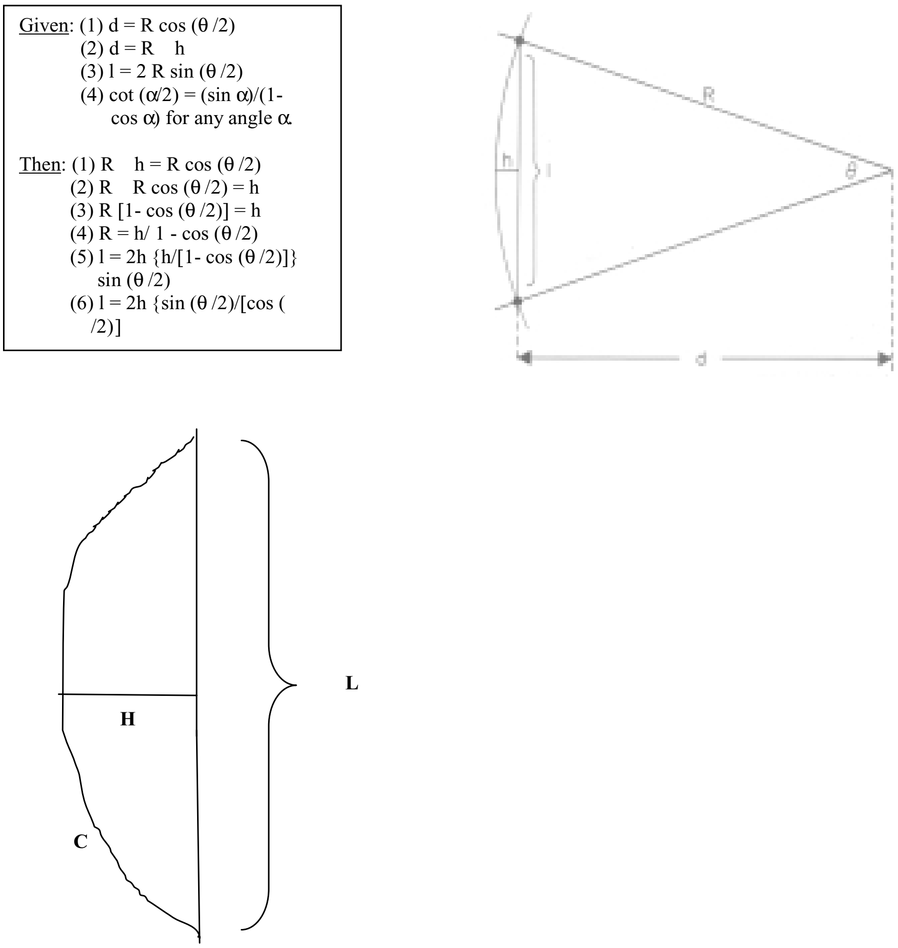
Patients kept a log of their exercise activities. In addition, the research assistant contacted the patients by phone every-other-week during the study to determine if any problems were encountered with the exercises and to encourage compliance. Levels of compliance were ultimately calculated from the log sheets by taking the number of days that the patients *completed* their exercise routine and dividing that by the number of days they were asked to exercise over the 13-week study (i.e., 52).

2.7. Procedures at discharge

At discharge, patients underwent the same kyphosis angle measurement process described earlier. The mean of those measures served as the post-participation angle of kyphosis. After the tracings were made, the lead researcher inquired as to the patient's group assignment. If the patient was in the experimental group, he/she was asked to produce the exercise log.

2.8. Statistical analyses

A mixed design analysis of variance (ANOVA) was used to compare pre- and post-participation kyphosis angles of the two groups. The effect of group assignment and interaction of group assignment with pre- and post-participation kyphosis angle measures was also measured. A linear regression analysis assessed whether or not exercise compliance influenced the change in kyphosis angles. The researchers elected to do the regression analysis post-hoc after discovering the groups' similarities with respect to both range and direction of kyphosis angle change over the du-



Kyphosis angle = 4 X (arc tan [2 H/L])

Fig. 3. Calculation of the kyphosis angle using the trigonometric method as described by Hart and Rose [8]. Original flexicurve tracing (C), height of curve (H) and length of the curve (L) are depicted.

ration of the study. The authors proposed that there would be no statistically significant difference (alpha < 0.05) between the control and experimental groups' delta kyphosis values.

3. Results

3.1. Assignment of participants to groups

Patients were randomly assigned to a group by rolling a die. The authors were blinded to group assignment until all data were collected on an individual patient. There were 39 control group patients. Four patients in the experimental group ($n = 32$) did not complete the study; one of these patients developed complications related to a pregnancy that she was unaware of upon admission to the study. The other three dropped out, of their own accord, due to their inability to maintain compliance with the exercises. None of these decisions were based on real or perceived complications arising from the exercise prescription. Thus, 71 patients (23 males and 48 females) completed the study.

3.2. Characteristics of the participants

The gender and group breakdown of the patients who completed the study was 13 males and 26 females (control) and 10 males and 22 females (experimental). The mean kyphosis angles for the two groups (minus those that dropped from the study) at intake were 44.6° ($\pm$

Table 1
Descriptive statistics (in degrees) for the mean pre- and post-participation levels of kyphosis for the two groups

	Descriptive Statistics				
	N	Minimum	Maximum	Mean	Std. Deviation
Control at beginning of study	39	23.00	80.02	44.6274	12.52552
Control at end of study	39	19.65	87.52	45.1344	13.35436
Experimental at beginning of study	32	30.50	69.40	46.4080	8.71060
Experimental at end of study	32	27.99	66.07	43.3894	9.59459

12.5°) and 46.4° (± 8.7°), for the control and experimental groups, respectively. The respective ranges of kyphoses for the two groups were 23°–80° and 30.5–69.4°.

3.3. Descriptive data and kyphosis angle changes

Descriptive statistics of the pre- and post-participation levels of kyphosis are shown in Table 1. The groups' mean pre-participation kyphosis angle measures were not statistically significantly different ($p =$ 0.499), as demonstrated by an independent samples' t-test. A comparison of the groups' kyphosis measures evaluated over time (delta kyphosis) demonstrated a statistically significant interaction ($p = 0.0283$) on the repeated measures ANOVA (Table 2). The delta kyphosis descriptive statistics are shown in Table 3. The mean change in kyphosis angles were 0.5° (±7.0°) for the control group and minus 3.0° (±6.1°) for the experimental group. (The negative value for the latter mean indicates a decrease in kyphosis from pre-to-post-study.)

A comparison of the four cells of delta kyphosis measures (i.e., pre- and post-participation measures for each group) produced only one statistically significant ($p =$ 0.0117) finding; that being the comparison between the pre- and post-participation measures of the experimental group. However, when the post-hoc Tukey-Kramer procedure was applied to adjust for multiple comparisons, the p-value for this same measure was 0.0557 (Table 4).

The authors considered whether or not patients who had a larger kyphosis angle initially responded better to the exercise interventions than those with smaller curves. Table 5 presents this analysis. No apparent relationship exists ($r = -0.196$; $p = 0.282$).

3.4. Power analysis

The study's 71 participants gave the overall model a power of 0.599. In consideration of the adjusted p-value (0.0557) relative to the alpha level (0.05), it is possible that the sample size was too small to detect a statistically significant difference in the post-hoc analyses.

Table 2
Repeated measures analysis of variance (ANOVA) for factors of time and time*group interaction

Effect	df	df	F value	Pr>F
Time	1	69	2.55	0.1150
Time*Group	1	69	5.02	0.0283
Group	1	69	0.00	0.9946

4. Discussion

4.1. Synthesis of statistical measures and error analyses

The present authors were interested in determining what amount of the delta kyphosis values were obtained as a result of the exercise interventions. At the 0.05 alpha level, there is evidence to suggest that the patients' group assignment had a statistically significant impact on their kyphosis angle change (Table 2). That is, there is statistical evidence to refute the null hypothesis. However, the mean kyphosis angle changes (Table 3) are of marginal *clinical* significance. The changes in both groups are within the range of measurement error from the lead author's pilot study.

Carman et al. [5], using the gold standard for kyphosis measures, established an 11° tolerance limit for kyphosis angle change to be labeled as "significant" on successive radiographs of the thoracic spine; meaning that the independent variable was responsible for the kyphosis angle changes. The current study's findings support this value as a reasonable tolerance level for significant kyphosis angle change. Finally, given the similarity of the delta kyphosis range and standard deviation values for the two groups in the present study, the mean angle changes of the experimental group appear relatively insignificant.

The results of the post-hoc analysis of the repeated-measures ANOVA indicated only one statistically sig-

Table 3
Descriptive statistics (in degrees) for the mean change in kyphosis values for the two groups

	N	Minimum	Maximum	Mean	Std. Deviation
Delta kyphosis control	39	−13.93	15.16	0.5069	6.99215
Delta kyphosis experimental	32	−12.52	13.74	−3.0181	6.07639
Valid N	32				

Table 4
Adjusted post-hoc analysis (Tukey-Kramer adjustment for Differences of Least Squares Mean) of the time*group interaction of kyphosis angle measurements

Effect	Time	Group	Time	Group	Adj P
Time*Group	1	1	1	2	0.9136
Time*Group	1	1	2	1	0.9633
Time*Group	1	1	2	2	0.9684
Time*Group	1	2	2	1	0.9658
Time*Group	1	2	2	2	0.0557
Time*Group	2	1	2	2	0.9181

nificant ($p = 0.0117$) comparison; i.e., the comparison between the pre-and post-participation measures of kyphosis angle for the experimental group. But, an adjusted comparison of the groups (Table 4) produced a p-value slightly above the 0.05 alpha level established a priori for this study. The adjusted p-value considers the fact that multiple comparisons were made in the repeated-measures ANOVA and adjusts the alpha value used to determine statistical significance. Still, a Type II error is possible, as noted earlier, since the post-hoc analysis demonstrated only 60% power for the study.

The study's linear regression analysis demonstrated a poor relationship between changes in kyphosis angles and the patients' levels of compliance. A couple of considerations must be taken into account in this analysis. First, patients exercised independently and may have performed with marginal precision. In addition, their compliance was self-reported. Even though it was the intent of the authors to reflect a common clinical practice pattern for postural interventions, it is unknown how accurate the self-reported compliance values are. A combination of factors, including minimal exercise supervision by a physical therapist, responsibility for compliance in the patients' hands, and a limited number of patient visits, may all have contributed to the marginal statistical relevance of the delta kyphosis values. Inasmuch, these results may underscore the futility of managing postural abnormalities within the scope of this (limited visit/self management) practice pattern.

4.2. Implications for future studies and clinical practice

Very little longitudinal research has evaluated the influence of therapeutic exercise interventions on spinal posture [10,24]. Only a few objectively measured the angle of kyphosis; instead, the authors evaluated patients' symptomatic or functional responses to exercise interventions. This study highlights a key issue for future practice and research efforts related to therapeutic interventions for static spinal posture. Normal postural variability over time must be considered. Bullock-Saxton [4] demonstrated, in symptom-free adults, that postural "memory" is quite remarkable over a two-year period. This study does not demonstrate that same degree of consistent postural presentation. Lundon et al. [15] attributed the majority of the changeability in repeated kyphosis angle measures in their study to patient variables, as opposed to issues of measurement reliability. This uncertainty with respect to normal postural variability has implications for those who evaluate changes in posture resulting from therapeutic intervention. To date, this has not been a primary consideration.

Finally, future researchers and practitioners must establish their own measurement error values with a particular instrument. Postural variability and/or measurement error must account for the majority of the range of kyphosis values seen in the control group. The results of the lead author's pilot study minimize the probable influence of measurement error in the current study. Furthermore, the values of statistical significance, delta kyphosis, and standard deviation in the Itoi and Sinaki [11] study closely reflect the values obtained in the current study. This similarity is remarkable. The results suggest reasonable prescriptive validity of the current study's non-invasive, flexicurve measurement technique as well as the potential variability in postural presentations.

5. Conclusion

This prospective study of the effect of exercise interventions on postural kyphosis demonstrated a statistically significant difference between a group of exercisers and non-exercisers, with patients in the exercising group demonstrating more improvement in their kyphosis angle measures. However, post-hoc adjustments to the model placed the significance value just above the alpha level. In addition, the clinical signifi-

Table 5
Correlation analysis of pre-participation angle of kyphosis and delta kyphosis values

Correlations[a]			
		Entry	Delta kyphosis
Entry	Pearson Correlation	1	−0.196
	(Sig. 2-tailed)		0.282
	N 32	32	
Delta kyphosis	Pearson Correlation	−0.196	1
	(Sig. 2-tailed)	0.282	
	N	32	32

[a]Group = experimental.

cance of the measured kyphosis angle changes is questionable since the amount of change is negligible in the context of cosmetic, functional, or therapeutic values. These conclusions are similar to the preponderance of literature evaluating the influence of exercise on postural alignment. However, since patients exercised independently and were solely accountable for their compliance, future studies are warranted. A larger sample size would also add to the efficacy of future studies.

The primary differences between this study and the majority of earlier studies are the presence of a control group, blinded measurement, and the thoroughness of the exercise prescription that specifically targeted thoracic kyphosis. Future studies should also take these factors into account. Given the range of variability seen in this and several other studies cited herein, the authors suggest that it is essential to future studies that postural variability standards first be established and then considered in subsequent data interpretation. Since the range of variability in the patients' pre- and post-participation levels of kyphosis reflect both increases and decreases in the measured angles across the spectrum of compliance levels, it is possible that there is simply more variation in patients' posture than the authors anticipated. Until this question is fully addressed, clinical monitoring of kyphosis angle changes over time has limited value. The current study, as well as that by Carman et al. [5], highlights the likelihood of noteworthy variations in the linear assessment of postural presentations.

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Appendix 1.

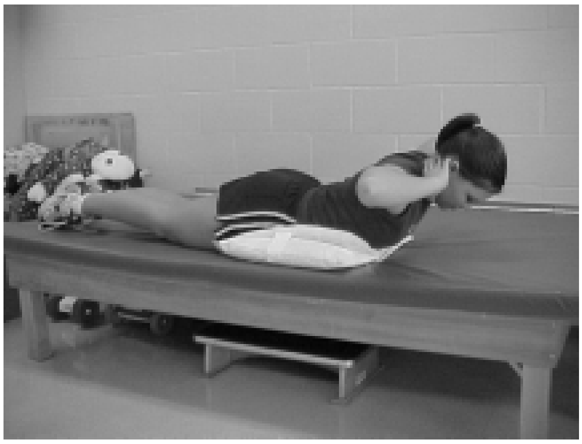


Fig. 4. Four-step prone back extension. Start: arms raised from the floor, thorax raised from the floor, thorax lowered to floor, and arms lowered to the floor. This exercise was progressed to elbows fully extended and arms abducted approximately 125° in the frontal plane.

Fig. 5. Shoulder horizontal abduction/scapular adduction 4-step exercise. Start: arms elevated at 90° in front of the body (as shown). Then, shoulders horizontally abducted to frontal plane, scapulae adducted, scapulae return to initial position, and arms reach forward again. Exercise progressed to one higher level of band resistance.

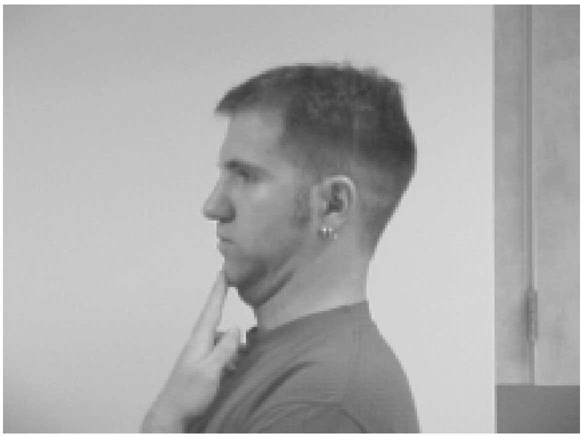
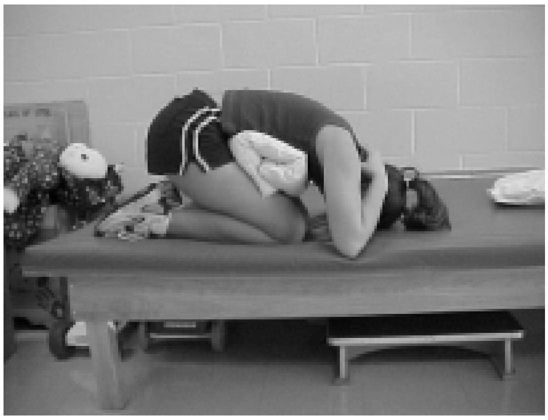


Fig. 6. Cervical retraction exercise. Patient repeatedly emphasizes upper cervical flexion with lower cervical/upper thoracic extension; alternating position with the opposite (resting) cervical posture.

Fig. 7. Self-mobilization of the thoracic spine into extension with a Styrofoam roll.

(A)



(B)

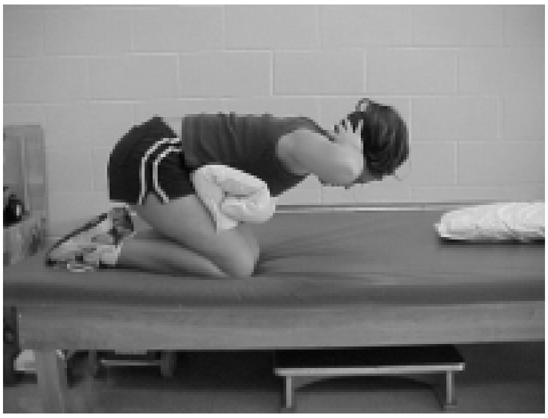


Fig. 8. Thoracic extension exercise. (A) Patient begins in cervical, lumbar and thoracic flexion. She then is instructed to extend neck and thoracic spines on a segment-by-segment basis. She adducts scapulae at end of exercise. Pillow placed to encourage maintenance of *relative* lumbar flexion.

Fig. 9. Yoga exercise to strengthen back extensors. Patient starts from flexed thoracic spine and arms internally rotated. Progresses to arms outwardly rotated and thorax extended (as shown). Leg position facilitates emphasis of extension into thoracic spine, versus lumbar.

Fig. 10. Latissimus Dorsi and Pectoralis Major stretch exercise. Patient starts in “90-90” position of shoulders/elbows with arms relaxed on floor as shown. Patient takes arms overhead as far as possible. Goal is full elevation of arms overhead without losing floor contact. Leg position restricts compensatory lumbar extension.

Appendix 2.

(A)

(B)

Fig. 11. Alternative exercise for patients unable to do exercise shown in Fig. 8. Patient alternately flexes (A) and extends (B) thoracic spine from all-4’s position; emphasis on extension of thorax. Arms remain locked at elbows.

Fig. 12. Alternative exercise for patients unable to do exercise shown in Fig. 7. Patient performs self mobilization of thoracic spine into extension by sliding roller up and down thoracic region through knee bending and straightening while holding self as erect as possible against the Styrofoam roll.