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Yoga Improves Upper-Extremity Function and Scapular Posturing in Persons with Hyperkyphosis

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Abstract

Objective: Hyperkyphosis (excess thoracic spine curvature) is associated with upper-extremity functional limitations and altered scapular posturing. The purpose of this study was to quantify the changes in upper-extremity function and scapular posturing following a 6-month yogaintervention in persons with hyperkyphosis.

Methods: Twenty-one older adults with hyperkyphosis (75.5+7.4 yrs) enrolled in the UCLA Yoga for Kyphosis randomized controlled trial, elected to participate in this uncontrolled, prepost substudy of upper-extremity function. They were measured at baseline and after a 24-week yoga intervention. Maximum vertical reach and timed book tests were used to evaluate upper-extremity function. Scapular posturing was quantified using a motion analysis system and data was obtained under 4 conditions: 1) quiet-standing, 2) normal walking, 3) fast walking, and 4) seated. Paired t-tests were used to test for changes between baseline and 6-month follow-up measures and Cohen's *d* was calculated to examine effect sizes.

Results: Following the 6-month yoga intervention, participants improved their book test performance by 26.4% ($p < 0.001$; $d = 1.5$). Scapular protraction decreased by 2.9% during the static-sitting condition ($p < 0.001$; $d = 0.5$) and the overall excursion of the scapulae decreased for both fast (25.0%, $p < 0.05$; $d = 0.6$) and self-selected walking (29.4%, $p < 0.01$; $d = 0.9$). There were no changes in maximum vertical reach.

Conclusion: Subjects demonstrated significant improvements with small to large effect sizes in the timed book test and scapular posturing to a less protracted position during both static and dynamic conditions after the intervention. These adaptations are likely to reduce the risk of scapular impingement and help preserve functional independence in older adults.

Keywords: Hyperkyphosis; Upper-extremity function; Scapular posture; Yoga

Introduction

Hyperkyphosis, or excessive thoracic curvature, is common among older adults, affecting up to two-thirds of senior women and one-half of senior men [1]. Its associations with thoracic back pain, decreased strength, compromised respiratory function, limitations in activities of daily living and mortality, have been described [2-8]. Less appreciated is that hyperkyphosis may be particularly detrimental to upper-extremity physical function, because as thoracic curvature increases, the scapulae assume a more protracted, elevated, downwardly rotated, and anteriorly tilted position [9-12]. This 3-dimensional position decreases the subacromial space and increases the risk and severity of subacromial impingement. The relatively high prevalence of impingement syndromes and rotator cuff tears in older adults may be partly due to hyperkyphosis and its altered scapular positioning [13-17]. Limitations in upper-extremity range of motion (ROM) and physical function may also result from hyperkyphosis-associated restrictions in scapular range of movement [12,18-21]. Adequate upper-extremity ROM is essential to carrying out basic activities of daily living (ADLs) such as grooming, attending to personal hygiene and dressing [19,21]. We recently reported the results of a 6-month randomized controlled trial of yoga for seniors with hyperkyphosis, in which participants successfully decreased their resting kyphosis angle [22]. Here, we conducted a substudy within that trial, a single-armed, biomechanical investigation of upper-extremity mobility and physical function. The aims of the study were to quantify baseline and 6-month upper-extremity functional performance and scapular posturing and to assess whether yoga favorably affected these characteristics. We hypothesized that timed book test performance, maximum vertical reach, and scapular posturing, would improve following the 6-month yoga intervention.

Methods

Study design

The parent study, Yoga for Kyphosis trial conducted at University of California, Los Angeles (UCLA), was a randomized – controlled clinical trial (RCT) of a specially-designed yoga program. It included 118 women and men, aged 60 years or greater. The parent study yoga program and primary results have been described previously [22]. Participants in the Yoga for Kyphosis RCT, who were randomized to a control-intervention group (n=35), were invited to participate in a substudy at the University of Southern California (USC), examining changes in upper-extremity biomechanics. The control intervention was intended to provide a social environment similar to Yoga and included lunch seminars designed to provide emotionally positive and

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intellectually stimulating socialization experiences. Control participants also received a monthly newsletter and a senior health magazine. At the end of the control intervention period, that group received “delayed yoga”; that is, they received the same yoga intervention as the initial active treatment group. The substudy was initiated at the onset of the delayed yoga intervention phase and was therefore uncontrolled. A total of 21 participants in the control-intervention group agreed to participate in the substudy. The USC and UCLA Institutional Review Boards approved the study protocol and participants provided written, informed consent.

Eligibility criteria

Women and men aged 60 years or greater with adult-onset hyperkyphosis (Debrunner kyphometer angle was > 40 degrees) were eligible for the parent study [23-24]. Exclusion criteria included significant comorbidity that would make it unsafe to participate in the yoga intervention (e.g. active angina, unstable asthma, chronic obstructive pulmonary disease, cervical spine instability, unstable knee or shoulder joints, use of an assistive walking device or inability to hear or see adequately for participation). Participants also had to execute the following safety tests independently and with safe postural control: transition from standing to sitting on the floor and get up from the floor to standing; lift both arms to shoulder level; stand with feet side-by-side for 30 seconds; and stand with feet hip-width apart for 60 seconds. The safety tests were employed to minimize the risk of injury while performing the poses and transitioning between poses. Safety test performance was recorded as pass or no-pass. Per study requisite, all participants (n = 21) in the sub-study passed the safety tests.

Sub-study measurements

This substudy measured upper-extremity function (timed book test and vertical reach) and scapular posturing. All tests were conducted at baseline and following 24-weeks of yoga intervention.

Upper-extremity function: Upper extremity function was assessed using 3 measures: 1) maximum standing vertical reach, 2) maximum seated vertical reach, and 3) a timed book test. A research associate demonstrated each test to the participants and explicit, uniform verbal instructions were provided. Three successful trials were collected for each test, and the best performance was used for analysis. During the vertical-reach tasks, reflective markers were placed on the 3rd distal phalanx of both hands. The positions of the markers were recorded with an 8-camera motion analysis system (Vicon 612, Oxford Metrics, Oxford, UK). For standing the vertical reach task, participants were instructed to walk at their normal, comfortable speed, stop next to a safety bar, and wait for instruction. The participants were then given the following standard instructions: “To ensure your safety, please place your right hand gently on the safety bar. The safety bar is for you to use in case you lose your balance. This is not to be used to assist your movement, so please don’t grasp it tightly or push on it. When you are ready, bring your left arm forward slowly. While keeping your arm straight, lift it up, and try to reach as high as you can. Once you think you have reached the highest point, you can then bring your arm back again, from the forward direction. Your feet should always remain flat in contact with the ground.” During the seated maximum reach task, participants were instructed to stand, shake and relax their shoulders and arms, then sit down with their arms at their side. The participant was then asked to perform a vertical reach “as high as you can, just like you did for the standing reaching test”. This test was repeated with the right arm, the left arm, and both arms together. The chair height was adjusted to the height of each participant’s fibular head. The distance of the participant’s 3rd distal phalanx marker from the laboratory floor was calculated as the maximum vertical reach distance. This distance was then normalized by body height for further analysis. The timed book test assessed upper extremity power in seniors [25]. Subjects were asked to lift a book from a table, place it on a shelf, and then return it to the table, 5 consecutive times (Figure 1). The book weight was standardized to 2% of each subject’s body weight. The table and shelf height were standardized as follows: 1) subject forearm length (ulnar olecranon process to ulnar head) was used to position the shelf, above each seated subject’s acromion process (shoulder). The table was positioned at the level of each participant’s olecranon process (elbow). These heights were recorded and used at baseline and during the follow-up measurements. The specific participant instructions were as follows: “lift the book from the table, place it upon the shelf, and then return it to the table, 5 consecutive times, as fast as you can. When the book touches the shelf, you can then immediately bring the book back to the table. You do not need to release the book on the table or the shelf from your hand during the test.” This methodology demonstrates excellent reliability in our laboratory, with a 7-day testretest Intraclass Correlation Coefficient [ICC (2, k)] of 0.96 [26].

Scapular posturing: Scapular posturing was assessed under 4 conditions: 1) quiet-standing, 2) normal walking, 3) fast walking, and 4) seated, in a randomized order. The position of the scapulae were quantified by tracking reflective markers, via the 8-camera motion analysis system, placed on the 7th cervical spinous process (C7), sternal notch (St) and bilateral acromion processes (RA, LA). The relative position of the scapulae was calculated as: [(distance from C7 to RA) + (distance from C7 to LA)] / [(distance from St to RA) + (distance from St to LA)]. A value of greater than 1 reflects a more protracted position whereas a value less than 1 reflects a more retracted position. Scapular position was averaged across 3 trials, under each of the 4 conditions. Because walking is a dynamic task and scapular position varies across the gait cycle, the maximum, minimum, and average scapular positions, during the gait cycle, were calculated to capture the dynamic range of the scapular posturing. Additionally, the difference between the maximum and minimum scapular protraction during the gait cycle was calculated to measure scapular excursion. For the standing measurement, subjects were instructed to walk a short distance and then stop and hold a comfortable standing position for 10 seconds. During the walking measurements, subjects were instructed to walk at two speeds over a 6 meter distance: 1) self-selected and 2)

Figure 1: Modified timed book test: a participant lifts and replaces a book, equal to 2% of body weight, from a table to a shelf, as fast as possible, 5 continuous times, while seated. The height of the chair, table, and shelf are subject-specific.

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"at a speed you would use to cross a busy intersection". For the seated measurement, the subjects were instructed to walk a short distance, stop, and sit upon a firm backless chair. They then rested "comfortably" for 10 seconds. This methodology demonstrates excellent reliability in our laboratory with 7-day test-retest ICCs (2, k) ranging from 0.88 to 0.93 across the standing, walking, and seated measurements.

Yoga intervention

The intervention, which is detailed in the parent study, was a customized Hatha yoga program designed for seniors with hyperkyphosis [22]. In brief, standard poses (Table 1) were modified to target the mutable causes of hyperkyphosis (e.g. tight connective and myotendinous tissues) in the context of the physical limitations of this population. The program contained 4 progressive series of poses, which targeted flexibility, strength, and proprioceptive awareness, of the major trunk and appendicular muscle/tendon groups. Classes were held 3 days per week, 1 hour per session, for 24 weeks.

Data analyses

Student's paired t-tests were employed to compare differences in the outcome measures of upper-extremity functional performance

Series 1: Supine on Floor with knees bent and spine & head supported	
Pose (Asana**)**	**Movement**
3-part breath (dirga pranayama)	Inhale and exhale segmentally into belly, ribs and chest
Shoulder girdle press (setu bandhasana prep)	Press scapulae toward chest and press shoulders into extension
Arms to sky (supta ardha hastasana)	Lift arms to 90 degrees of flexion and return arms by sides
Neck stretch (jalandhara bandha)	Rotate shoulder blades (scapulae) towards chest and chin drops toward sternum
Arms overhead (supta utthita hastasana)	Take arms into full flexion and return
Leg extension (ardha supta tadasana)	Extend one leg on exhale and return on inhale, then both legs together
Half bridge (ardha setu bandhasana)	On exhale, curl pelvis and lift hips, inhale release hips
Knees to chest (ardha apanasana)	Draw one knee to chest at a time and hold
Twist (jathara parivartanasana)	With lower back in flexion, draw both knees to one side with support
Wing press	Abduct shoulder and flex elbows 90 degrees, pressing arms into floor
Series 2: Seated in a chair with support for neutral pelvis	
Pose (Asana)	**Movement**
Victorius breath (ujjayi pranayama)	Lengthen inhales and exhales, slightly constricting throat
Arms forward and up (utthita hastasana)	Bring one arm into full flexion, alternate, then both arms
Prayer hands (namaste vinyasa)	Palms press into each other at chest and open arms into 90 degrees of abduction
Cow face (gomukhasana)	Using strap in hands for support, one arm in full shoulder and elbow flexion and opposite arm behind back in shoulder extension and elbow flexion, both sides
Cobra (bhujangasana)	A. Retract scapuae and extend thoracic spine and release B. Extend shoulders and place hands on back of chair and repeat actions
Warrior 2 (virabhadrasana II)	Front hip in external rotation and knee flexion and opposite leg straight and arms in 90 degrees of abduction
Leg lifts (uttitha hasta pandhangustasana)	A. Lift one foot off floor and return and alternate legs B. Extend knee and lift leg and return with alternate legs
Twist (bharadvajasana)	Axial rotation of thoracic and cervical spine using hands as levers, change rotation of cervical spine
Sun Salute (surya namaskar)	Inhale while abducting arms and exhale releasing arms by side.
Pose (Asana)	**Movement**
Seated cross legged on blanket/Sukhasana with breath retention (kumbhaka pranayama)	Sitting crossed legged with support, inhale 4 counts, hold 2 counts, exhale 4 counts, hold with breath out 2 counts
Cat & cow pelvic tilts (marjariasana & bitilasana)	On all fours, A. Pelvic tilt , lumbar extension/flexion on breath B. Partial cow, Thoracic extension/flexion on breath C. Full cat/cow, coordinating A&B
Balancing cat & cow/prep for Warrior 3 (virabhadrasana III)	On all fours maintain neutral spine, A. Extend one knee and hip and return to all 4s B. Flex one shoulder and return to all 4s C. Contralateral, first lift one leg and add opposite arm
Locust (salabhasana I)	Blanket(s) under torso and lying prone and shoulders in 90 degrees of abduction, A. Lift arms slightly off floor B. Lift arms then chest slightly off floor C. A&B and add one leg lifting and alternate D. A, B C, both legs lift
Sphinx pose (bhujangasana prep)	From prone position, come onto forearms and press scapulae back and stretch chest while engaging abs
Locust (salabhasana II)	Blanket(s) under torso and lying prone with shoulders in full flexion, A. Contralateral lift of one arm and one leg and alternate B. Lift only legs C. Lift legs and then arms
Knees to chest (apanasana)	Turn onto back and hug knees to chest
Twist (jathara parivartanasana)	With lower back in flexion, draw both knees to one side with support
Series 4: Standing with chair for balance as needed	
Pose (Asana)	**Movement**
Breath retention (kumbhaka pranayama)	Lying on back with support and knees bent, inhale halfway and hold 2 counts, then inhale fully and hold 2 counts, exhale completely
Mountain (tadasana)	Standing with feet hip width
Chair (utkatasana)	Standing with feet hip width, inhale and lift arms into full flexion and exhale into deep knee flexion with minimal hip flexion A. Standing with back on wall and feet away from wall as knees flex and shoulders flex 90 degrees B. Same as B. with arms in full flexion
Mountain sway (tadasana sway)	Shift weight forward and back, side to side and circles from ankles in both directions, maintaining neutral pelvis and spine
Standing shoulder stretch (tadasana with setu bandhasana arms)	While standing, externally rotate and extend shoulders and clasp hands behind back
¼ sun salute and hold arms up (¼ surya namaskar with hastasana)	Stand and abduct arms, exhale arms by side
Warrior 1 (virabhadrasana I)	Tandem stance with feet hip width, front knee bends and opposite arm flexes and back leg straight; hand on chair for balance
Puppy dog (ardha adho mukha svanasana)	Hands on wall in full wrist extension, shoulder flexion, spine neutral with hips in flexion and knees extended as hamstrings allow
4-footed staff or wall pushup (chaturanga dandasana)	Stand facing wall, arm's length away from wall, wrists in extension and flex elbows with neutral spine and hips, and extend elbows, like a pushup

Table 1: Hatha Yoga program for persons with hyperkyphosis: 4 progressive series.

and scapular posturing, between baseline and 6 month follow-up time points. Additionally, Cohen's d effect sizes (small d = 0.2; medium d = 0.5; large d = 0.8) are reported for all statistically significant post-hoc comparisons [27]. All the statistical procedures were conducted using SPSS version 16.0 statistical analysis software (Chicago, IL, USA).

Results

Participant characteristics

The mean age of the participants in the parent study (n=118) was 75.5 ± 7.4 years. They were predominantly women (81%) and Caucasian (88%). The average kyphotic angle measured by Debrunner kyphometer, height, weight, and body mass index were 57.9 + 9.6 degrees, 160.0 + 8.8 cm, 68.2 + 15.2 kg, and 26.5 + 4.6 (kg/m^2), respectively. None of these anthropometric measures differed from those of subjects in the substudy-as indicated by the independent t-test analyses (p values ranged from 0.2 to 1.0). The average age, height, and weight of the substudy participants (N=21) were 75.3 + 7.0 yrs, 162.9 + 10.1 cm and 68.6 + 11.7 kg, respectively. The average body mass index was 25.8 + 3.3 (kg/m^2), and the average baseline kyphosis angle was 52.2 + 9.6 degrees. All of the participants that volunteered for the upper-extremity substudy passed the safety tests and completed the 24-week yoga program.

Upper-extremity function

Timed Book Test: At baseline, participants required an average time of 8.21 + 1.76 seconds to complete the 5 repetitions. Following 24-weeks of yoga participation, subjects improved their time to complete the test by an average of 3.03 ± 2.46 seconds (a 26.4% improvement; $p < 0.001$; d = 1.5).

Vertical reach: Neither standing (p = 0.19-1.00) nor seated (p = 0.60-0.86) reach height differed between the baseline and follow-up measurements.

Scapular posturing

After 24-weeks of yoga intervention, average scapular posturing, during quiet sitting, improved by 2.9% (less protracted position, $p < 0.01$; d = 0.5) (Table 2). Diminished protraction was also observed during static standing, however, the difference was of borderline statistical significance (p = 0.06; d = 0.2). During dynamic walking, maximum scapular protraction decreased by 1.9% during self-selected walking ($p < 0.05$, d = 0.4) and 1.3% during the fast walking condition ($p < 0.05$, d = 0.3). The overall excursion of the scapulae decreased significantly after the 6-month yoga intervention for both the self-selected walking (29.4% change, $p < 0.01$; d = 0.9) and fast walking (25.0% change, $p < 0.05$; d = 0.6) conditions.

	Baseline	Follow-up	P-value
Static Sitting	1.068 + 0.049	1.037 + 0.065	0.001
Static Standing	1.051 + 0.048	1.040 + 0.059	0.059
Self-selected Walking			
Maximum	1.037 + 0.043	1.017 + 0.051	0.014
Minimum	1.020 + 0.042	1.022 + 0.052	0.685
Average	1.028 + 0.043	1.011 + 0.052	0.020
Excursion	0.017 + 0.006	0.012 + 0.005	0.005
Fast Walking			
Maximum	1.043 + 0.044	1.029 + 0.046	0.026
Minimum	1.015 + 0.042	1.009 + 0.052	0.197
Average	1.030 + 0.043	1.019 + 0.048	0.053
Excursion	0.028 + 0.010	0.021 + 0.014	0.035

*Scapular position was calculated as: [(distance from C7 spinous process to Right Acromion) + (distance from C7 to Left Acromion)] / [(distance from Sternum to Right Acromion) + (distance from Sternum to Left Acromion)]. A value of greater than 1 reflects a more protracted position; whereas a value less than 1 reflects a more retracted position.

Table 2: Scapular position* during static sitting, static standing, self-selected walking and fast walking.

Discussion

Following 6-months of participation in a yoga program designed to reduce hyperkyphosis, study participants experienced significant improvements in the timed book test (large effect size) and scapular posturing (e.g. they assumed a less protracted position, during both static and dynamic testing conditions) (small to large effect size). The scapulae were also more stable, as indicated by a significantly decreased scapular excursion, during both normal and fast walking. Changes were not evident for the maximum reach measures. Improvement in the timed book test is consistent with our *a priori* hypotheses and likely the result of participation in a program designed specifically to target myotendinous structures of the shoulder girdle and glenohumeral joint [22]. Poses in which the arms were held aloft (e.g. wall push-up [chaturanga dandasana] and the warrior series) were likely to target the deltoids, pectoralis muscles, rotator-cuff muscles, trapezius, and bicep brachii, and triceps brachii. These muscles are also agonists for the stabilization of the shoulder girdle, and for shoulder and elbow flexion/extension-which are the primary movement patterns needed to execute the timed book test. Future biomechanical analyses, which incorporate an electromyographic study of the poses, will be helpful in determining which poses were likely to have had the greatest influence on these functional improvements. Also consistent with our hypothesis, the participants demonstrated improved scapular posturing (less protracted position) during static sitting and walking, at both self-selected and fast speeds. There was also a trend toward improved scapular posturing during static standing. We believe the findings can be attributed to 3 primary factors: First, the inclusion of poses (e.g. Sphinx and standing shoulder stretch) which we believed would stretch the anterior myotendinous structures of the shoulder girdle and allow the scapulae to assume a more retracted position; second, the inclusion of poses (e.g. locust and wing press) we believed would strengthen the retractors of the scapulae (e.g. rhomboids and trapezius) and thus hold the scapulae in the more retracted position; and third, yoga's emphasis on body posture, body awareness, and body-segment positioning, during asana performance. In regards to factors 1 and 2, future biomechanical studies which quantify the physical demands of yoga posing will be necessary to verify that the poses we included in the program to "stretch the anterior myotendinous structures" and "strengthen the retractors of the scapulae" actually have these beneficial characteristics. In regards to factor 3, longer-term studies will be needed in order to determine how long these postural carry-over effects persist. In contrast to our *a priori* hypothesis, maximum vertical reach distances did not change following the intervention. With hyperkyphosis, the scapulae assume a more protracted, elevated, downwardly rotated, and anteriorly tilted position [9-12]. This 3-dimensional profile decreases the subacromial space and increases the risk of impingement syndromes. With these risk factors in mind, our participants were instructed not to raise their arms to extreme positions during performance of the asanas. These instructions, however, which were instituted in order prevent shoulder impingement syndromes, may have also inadvertently limited any vertical-reach training effects. Future studies which examine the relations between upperextremity ROM during yoga and impingement risk will be needed before valid recommendations regarding ROM limitations, especially in persons with hyperkyphosis, can be put forward. Previous yoga investigations in seniors have demonstrated that regular practice can increase physical performance across a variety of measures. For example, a series of studies conducted by Chen and colleagues in community-dwelling older adults (2008) and frail elders (2010) reported that 24 weeks of yoga participation increased ROM, strength, and walking speed [28-29]. Oken (2006) demonstrated improvements in timed one-legged standing and forward flexibility, as well as quality of life, following a 6-month Hatha yoga program [30]. Improved walking performance of peak extension angle and stride length was also evident after 8-week practice of Iyengar Yoga [31].

Our substudy, however, is the first to report the effects of yoga on upper-extremity physical function and scapular posturing. Upper-extremity function is important and related to disability and independent living [32-33] in seniors. Moreover, as mentioned above, improper scapular posturing, which is associated with hyperkyphosis, can lead to impingement and injury. Consequently, it is important that physical activity programs incorporate exercises and movement patterns that address upper-extremity strength and ROM limitations-without increasing the risk of impingement syndromes. Although longer-term, RCTs will be needed to determine if yoga is an ideal activity to address these issues, this small, pre-post, substudy, provides preliminary evidence that yoga is indeed effective in persons with hyperkyphosis. Although we used well-practiced upper-extremity methodologies that are highly reliable in our laboratory, an obvious and important limitation of this substudy is the absence of a control group. Initial funding limitations precluded inclusion of these upper-extremity measurements in the original parent study, which was a RCT, and included a controlled-intervention group. It was not until this control group had switched-over to the yoga intervention that we received the additional funds to conduct the substudy-consequently, we were limited to a pre-post design. A second limitation of the study is that the participants were predominately Caucasian (88%) and women (80%); thus, our ability to extrapolate our findings to men and persons of additional races is limited. Expanded studies that include more men and participants with greater racial diversity will be needed to determine if our findings are robust and applicable to a more heterogeneous population. Nonetheless, our findings highlight the potential beneficial effects yoga may have on upper-extremity function; thus, we believe it is prudent that future yoga RCTs include, *a priori*, similar measures of upper-extremity performance and scapular posturing.

Conclusions

This is the first study to identify significant improvements in upper-extremity function and scapular posturing following yoga intervention in persons with hyperkyphosis. Upper-extremity function is important for activities of daily living and functional independence, and abnormal scapular positioning increases the risk of impingement syndromes. Positive results from this substudy suggest a potential alternative intervention for older adults with hyperkyphosis. Future RCTs will be necessary to confirm these findings.

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