Effects of group exercise on flexed posture, musculoskeletal impairments and physical performance in community-dwelling older women: a preliminary study

Katzman, Wendy

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**Effects of Group Exercise on Flexed Posture, Musculoskeletal Impairments and Physical Performance in Community-Dwelling Older Women: a Preliminary Study**

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Wendy Katzman PT, DPTSc Candidate

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# Changes in Flexed Posture, Musculoskeletal Impairments and Physical Performance Following Group Exercise in Community-Dwelling Older Women

Wendy B. Katzman DPTSc
Assistant Clinical Professor
University of California, San Francisco
UCSF Box 0625
San Francisco, CA 94143-0625
415-3533-7238, ext. 1 (vm)
415-353-9554 (fax)
Email: wendy.katzman@ucsfmedctr.org

Deborah E. Sellmeyer MD
Assistant Professor in Residence
University of California, San Francisco

Anita L. Stewart PhD
Professor in Residence
Institute for Health & Aging
University of California, San Francisco

Linda Wanek PhD
Associate Professor
San Francisco State University

Kate A. Hamel PhD
Assistant Professor
San Francisco State University
1600 Holloway St.
San Francisco, CA 94132
415-338-2186
hamelk@sfsu.edu

This study was carried out in part in the General Clinical Research Center, Moffitt/MZ Hospital, University of California, San Francisco, with funds provided by the National Center for Research Resources, MO1 RR-00079, US Public Health Service. Additional funding provided by the CA PT Fund and the Mt. Zion Health Fund.

# Changes in Flexed Posture, Musculoskeletal Impairments and Physical Performance Following Group Exercise in Community-Dwelling Older Women

Wendy B. Katzman, Deborah E. Sellmeyer, Anita L. Stewart, Linda Wanek, Kate A. Hamel

**Objectives**: Flexed posture commonly increases with age and has been associated with impaired physical performance in older women. The purpose of this study was to determine whether improvements in flexed posture, strength, range of motion (ROM) and physical performance would be observed after 12-weeks of group exercise and to determine the relationship between baseline measurements, change in strength, change in ROM, change in physical performance, and change in flexed posture.

**Design:** Pretest posttest of outcome measures.

**Setting:** Outpatient academic medical center.

**Participants:** Twenty-one women with thoracic kyphosis ≥ 50°.

**Intervention:** Multi-dimensional group exercise performed 2x/week for 12 weeks.

**Measurements:** Primary dependent measures of flexed posture included kyphosis, forward head and height. Other dependent measures included spinal extensor muscle strength, shoulder/hip/ knee ROM, balance, Modified Physical Performance Test (PPT), Jug Test, and gait speed.

**Results:** Baseline kyphosis was 57°±5.0°, age was 72.0±4.2 years. At the end of the exercise program there were significant improvements in usual and best kyphosis (-6°±3°; -5°±3°, $p$<.001), spinal extensor muscle strength (21%±13% peak torque/body weight, $p$<.001), popliteal angle (right 7°±7°; left 9°±10°, $p$<.001), Modified PPT (2±2 points, $p$<.001), and Jug Test

(-1.4±1.3 s, $p<.001$). Age and Modified PPT at baseline correlated with change in kyphosis, r=0.5, $p=0.02$ and r=0.42, $p=0.055$ respectively. There were no other significant associations between baseline measurements, change in strength, change in ROM, or change in physical performance and change in flexed posture.

**Conclusion:** Multi-dimensional group exercise reduced measured kyphosis, improved strength, ROM and physical performance. This study provides a promising exercise intervention that may improve posture and physical performance in older women with flexed posture.

Key Words: older women, kyphosis, flexed posture, exercise

# Changes in Flexed Posture, Musculoskeletal Impairments, and Physical Performance Following Group Exercise in Community-Dwelling Older Women

## INTRODUCTION

Flexed posture commonly increases with age in older women, and is characterized by an excessive curvature in the thoracic spine (kyphosis), forward head posture and decline in height. [1-3] Kyphosis increases by 6 - 11% per decade over the age of 55 years even in women without vertebral fractures, and may be a significant risk factor for future fractures independent of low bone mineral density (BMD) or fracture history. [2-4] In studies of community-dwelling older women, the mean angle of kyphosis was 38° ± 14° for those a mean age of 68 years, increasing to 51° ± 16° for women a mean age of 82 years, with a diagnosis of osteoporosis and at least one vertebral compression fracture. [5] Increased kyphosis has been associated with greater difficulty performing activities of daily living (ADLs) and decline in physical performance. [1, 6-11] Women with increased kyphosis have impaired balance, slower walking and stair climbing speed, shorter functional reach, and decreased ability performing household activites.[1, 9, 10]

While the precise etiology of flexed posture is unknown, there are many underlying musculoskeletal, neuromuscular and sensory impairments associated with flexed posture. [1-3, 6, 12, 13 14] Often present without vertebral fractures, increased kyphosis has also been linked with vertebral compression fractures (VCF), and is thought to initiate spinal deformity in older individuals with low bone mass. [1-3, 11, 15-17] Impairments in spinal extension muscle strength and shoulder/hip range of motion (ROM) have been correlated with measures of flexed posture. [1, 11] Research suggests that women with increased kyphosis have impaired perception and integration of correct postural alignment, affecting balance and the ability to maintain normal upright posture.[10, 11, 18]

There has been limited research to determine whether improving the modifiable impairments of strength, ROM and postural alignment improves measures of flexed posture. Furthermore, it is not known whether improved measures of flexed posture will affect performance in balance, gait speed, and ADLs.

Previous studies have investigated methods to improve flexed posture, however these interventions are limited in number and scope. [19-22] None have investigated whether improving measures of flexed posture is associated with improved physical performance. Greendale and colleagues demonstrated improved forward head posture, timed ADL tasks and functional reach in a single group of hyper-kyphotic older women after a 12-week four yoga pose intervention; however, there was no change in measured kyphosis.[20] Itoi and colleagues reported improved kyphosis among hyper-kyphotic participants after a two-year trunk extension strengthening intervention, but there were no measures of physical performance.[19] Others found improved kyphosis, spinal extension strength and balance after a six-month spinal bracing intervention, which was surprising considering the passive nature of the intervention.[21] The most recent study of a single group of kyphotic women with osteoporosis reported improved measured height, spinal extension strength, balance and gait speed after a four-week spinal weighted orthosis, trunk extension and balance exercise program, but did not measure change in kyphosis.[22] These interventions were all limited in scope, difficult to apply clinically, did not target the multiple impairments associated with flexed posture, and did not examine the relationship between changes in measures of flexed posture and change in physical performance.

Changes in Flexed Posture Following Group Exercise

The primary purpose of this study was to determine if improvements in flexed posture, strength, ROM and physical performance would be observed after a 12-week multi-dimensional group exercise intervention in women 65 years of age and older. It was hypothesized that a targeted multi-dimensional exercise intervention designed to improve known strength, range of motion and postural alignment impairments associated with flexed posture would be associated with significant improvement in measures of flexed posture, strength, ROM, and physical performance.

A second aim was to determine whether baseline measures of age, bone density T-score, number of VCF, flexed posture, strength, ROM, physical performance, or change in measures of strength or ROM were associated with change in measures of flexed posture. It was hypothesized that baseline characteristics, change in strength and change in ROM would affect change in measures of flexed posture.

A third aim was to determine whether change in measures of flexed posture was associated with change in physical performance.

## METHODS

### Study Design

This experiment was a single group pretest - posttest design. Two pretest measurements were performed to determine test retest reliability and variability of all dependent measures. All participants were tested before and after a three-month group exercise intervention. The University of California, San Francisco Institutional Review Board (IRB) approved this study and all participants gave informed consent.

**Recruitment**

The population targeted for this study was women aged 65 years and older with flexed posture. Participants were recruited from the University of California, San Francisco Medical Center and San Francisco senior programs through mailings, flyers and public talks. Participants were required to have a thoracic kyphosis ≥ 50°, active thoracic extension range ≥ 5°, the ability to walk 1/4 mile without an assistive device, and be capable of climbing one flight of stairs independently. Approval to participate in a moderate intensity exercise program was required from a primary care physician. Participants were excluded for diagnosed vertebral compression fractures within the previous six months, serious medical conditions that would limit participation in the planned exercise program (including uncontrolled hypertension, type I diabetes, chest pain, myocardial infarction, or cardiac surgery within the previous 6 months), diagnosed vestibular or neurological disorder, total hip or knee replacement, or hip fracture within the previous 12 months, current use of sedative or hypnotic medications, 10 or more alcoholic drinks/weeks, oral glucocorticoid medications for six weeks or more the past year, non-English speaking, dementia or significant cognitive impairment (≤ 24 on the Mini Mental State Exam), or three or more falls the past year. Participants were instructed to maintain their prior activity level once enrolled in the study.

**Intervention**

Participants engaged in a group exercise intervention twice per week for 12-weeks and were asked to perform daily independent postural alignment correction at home. Exercises targeted multiple musculoskeletal impairments associated with measures of flexed posture including spinal extensor muscle strength, thoracic spine, shoulder and hip ROM, and postural alignment. [1, 6, 10, 11] A sensory-integration approach was used to teach participants to recognize correct postural alignment and consciously practice correct alignment at least three times a day. Participants were instructed to maintain proper spinal alignment during ADLs and during the group exercise program.

Specific exercises included thoracic extension, shoulder flexion and hip extension stretching, trunk extension and scapular muscle strengthening, transverses abdominus stabilization, and postural alignment training (Appendix 1). The strengthening regimen used high-intensity, progressive resistive exercise principles and the stretching regimen incorporated foam rollers and stretch straps. [23-25] For spinal extension strengthening, participants performed prone trunk extension to neutral against gravity, starting without weights and progressing through a series of three prone postures prior to adding hand-held dumbbells.[26] Spinal rotation and extension strengthening exercises were performed side-lying with theraband® (Thera-band®, Akron, Ohio) and quadruped with weights. For all strengthening exercises, weight or theraband® resistance was increased once a participant could perform three sets of eight repetitions with proper form, and without pain or discomfort. Weights were increased from one pound, in one pound increments, and theraband® resistance increased, progressing from yellow to red to green to blue theraband® (corresponding to two to 10 pounds of force for each percentage of theraband® strain).[26, 27]

Motivational interviewing and educational incentives helped identify barriers to participation and improve the drive to exercise. [28, 29] Informal weekly interviewing identified difficulties participants encountered with the exercises and adjustments were made accordingly. Participants were given educational handouts about normal postural alignment, posture exercises, integration of good posture into ADLs, recommended amounts of calcium and vitamin D, and home safety.[30-32]

**MEASURES**

Primary dependent measures of flexed posture, strength, ROM and physical performance were performed at three time points. Measurements were repeated at Time1 (T1), Time 2 (T2) one week later, and Time 3 (T3) after 12-weeks of group exercise. T1 and T2 measures were used to calculate test retest reliability with intraclass correlation coefficient (ICC) (3,1), and test retest differences in T1 and T2 measurements were calculated with paired t-tests.[33] T2 was used as the baseline and T3 as post-intervention measurement. The primary investigator performed all measurements, while a research assistant read and recorded. Most measurements were repeated three times and their mean used for statistical analysis. Specific measures are described below.

**Primary Outcome Measures**

***Flexed Posture***

Three primary outcome measures of flexed posture were identified for this study: thoracic kyphosis, forward head posture and height. Each measure was repeated during "usual" and "best" posture. "Usual" posture was standardized at full exhalation while "best" posture measurements were performed at full inhalation and cued to "stand as upright and tall as you can". Participants' feet were traced to ensure the same positioning on future measurement. Thoracic kyphosis defined as Cobb's angle between the 2$^{nd}$ and 3rd thoracic vertebrae and the 11$^{th}$ and 12$^{th}$ thoracic vertebra was measured with a Debrunner kyphometer (Proteck AG, Bern, Switzerland) using a standard protocol.[5] The researcher placed the kyphometer over appropriate landmarks and an assistant read and recorded the measurement. Height measurements were performed with a standard protocol using the Harbinger taximeter.[34] Forward head posture measurements were calculated as the distance from the tip of the tragus to the wall. Mantex Precision calipers (Haglof Sweden AB, Langsele, Sweden), adapted with a measurement level, were used as participants stood with their heels against a two-inch block to prevent trunk leaning.

All measurements had good test retest reliability (Table 1). T2-T1 test retest differences were non-significant (Table 2).

**Outcome Measures of Strength, ROM and Physical Performance**

Other outcome measures included two measures of spinal extension strength, six measures of ROM and seven measures of physical performance.

***Strength.*** Trunk extension muscle strength was measured using a trunk extension protocol on the Biodex 3 (Biodex Medical Systems, Inc, Shirley, New York) with the spine attachment. Participants were positioned in a modified sitting position with hips in 55° flexion, knees flexed between 35° and 40°, and feet supported. Participants performed three maximal 5-second trials with a 45 second rest between trials. Peak torque to body weight ratio was used for analysis. Prone trunk extension with a hand-held dynamometer, positioned over the 6th thoracic vertebrae at the spinous process, was used to measure trunk extension strength. Participants were positioned prone over two pillows supporting the trunk, and extended their trunk to neutral against resistance for 5-seconds.

Test retest reliability was good for Biodex trunk extension, however it was poor for the hand-held dynamometer (Table 1). There were no significant T2-T1 test retest differences (Table 2).

***Range of Motion.*** Six goniometry measurements were used to document ROM in the shoulders, hips and knees bilaterally. Bony landmarks were marked with a pen at full excursion to accommodate skin movement before all measurements. The researcher positioned the participant at end range, while an assistant positioned the goniometer, read and recorded measurements. ROM in shoulder flexion was measured supine with both hips and knees flexed until the lumbar spine flattened. [35] Popliteal angle was measured supine, one hip flexed to 90° and the opposite leg extended on the table.[36] Hip extension range of motion was measured supine with the modified Thomas Test, one hip flexed to 110°, while the opposite hip was moved into extension, not controlling the knee. [37]

Test retest reliability was good for all measurements except left shoulder flexion and left popliteal angle (Table 1). There were no significant T2-T1 test retest differences in ROM (Table 2).

***Physical Performance.*** Balance was measured using three tests of static and dynamic postural control. A standardized protocol for the Sensory Organization Test (SOT) on the Smart Balance Master (Neurocom, Clackamas, OR) was used to measure ability to use input from somatosensory, visual and vestibular systems to maintain balance.[38] Center of pressure (COP) velocity was calculated to assess body sway while standing on a force platform (Type 9286AA, Kistler Inst., Amherst, NY) with eyes closed for 30 seconds.[39] COP excursion during a dynamic leaning task was also assessed. Subjects were asked to lean as far forward and backward as possible with eyes open while COP data was recorded. COP excursion was calculated as the difference between greatest forward and backward lean, normalized to foot length. [40]

The Modified Physical Performance Test (PPT) described by Binder and colleagues, included seven standardized timed tasks (50-foot walk, don and remove a coat, pick up a penny from floor, stand-up five times from a chair, lift a 7-pound book to a shelf, climb one flight of stairs, and balance in semi-tandem, tandem and feet side-by-side positions) and two un-timed tasks of physical performance (climb four flights of stairs and turn 360°).[41] The Jug Test measured the time to transfer five one-gallon water-filled jugs (approximately 8.5 lbs.) from a low to high shelf, one jug at a time. [42] The low shelf was positioned at patella height and the high shelf at acromion height for each participant. Preferred gait speed was recorded using photocells at the beginning and end of a 25-foot course. Participants were instructed to walk at their "usual" speed.

All measurements had moderate to excellent test retest reliability (Table 1). T2-T1 test retest differences were not significant (Table2).

**Baseline Characteristics**

To examine baseline characteristics of bone mineral density (BMD) and vertebral compressions fractures (VCF) and their relationship to change in primary outcome measurements, all participants underwent testing for BMD and VCF.

***Bone Mineral Density and VCF.*** Bone mineral testing of the lumbar spine (L1-L4) was performed on a GE Lunar Prodigy machine (GE Medical Systems, Madison, Wisconsin), according to standard protocol and reviewed by the study physician. Lateral Vertebra Assessment (LVA) of T4 through L4 was performed according to protocol on the same machine, and semi-quantitative and quantitative assessments were completed by an experienced clinical densitometrist. A vertebral fracture was identified when a vertebral body had 20% or greater reduction in anterior, central or posterior height compared with adjacent vertebrae. [43]

### Statistical Analysis

Data analysis was completed using Minitab statistical software (Minitab, State College, PA). T-tests for paired comparisons were used to test for differences between baseline (T2) and post-intervention (T3) scores for each measure of flexed posture, strength, ROM and physical performance. Because of the number of outcome measures, we divided $\alpha = 0.05$ by 20, and established statistical significance at $p<.0025$.

Pearson correlation coefficients were used to test for correlations between baseline measures of age, BMD and physical performance and change in flexed posture, ($p<.05$). We examined the correlations between change in strength or ROM and change in flexed posture ($p<.05$). A mixed model ANOVA was used to examine the relationship between the number of VCF and change in flexed posture ($p<.05$).

We examined the correlations between change in flexed posture and change in physical performance ($p<.05$).

## RESULTS

Thirty-six participants were enrolled in the study after meeting all eligibility requirements. Eleven participants withdrew before the intervention phase: five participants changed their mind, three sustained non-study related injuries, two had balance problems and could not safely participate in the group intervention, and one admitted to modifying her "usual" posture at screening and no longer qualified. Of the 25 who began the intervention, three participants withdrew during the intervention phase due to non-study related injuries and one withdrew due to a family emergency. There were no injuries associated with study participation. Twenty-one participants completed the study and all 24 exercise sessions (Table 1). Participants who withdrew during the intervention were no different in age, kyphosis or BMD T-score than those who completed the study. Participants completing the study were 72 ± 4.2 years of age (mean ± SD), with lumbar spine BMD T-score–1.5 ± 1.3 and a median number of two VCF.

**Changes in Primary Outcome Measures**

***Change in Flexed Posture***

"Usual" kyphosis improved 6°± 3°and "best" kyphosis improved 5° ± 3° ($p$<.001) (Table 2). There were no significant changes in forward head posture or height ($p$>.0025).

***Change in Impairment Measures of Strength and ROM***

There was a significant increase in Biodex spinal extension strength (21% ± 13% peak torque/body weight, $p$<.001) (Table 2). There was no significant difference in prone trunk extension strength ($p$>.0025). Popliteal angle increased bilaterally (right 7° ± 7° and left 9° ± 10°, $p$<.001) (Table 2). There were no significant differences in shoulder flexion bilaterally or modified Thomas Test bilaterally ($p$>.0025).

***Change in Physical Performance***

There were no significant changes in balance measures of SOT, COP excursion or COP velocity, or gait speed ($p$>.0025). Timed Jug Test scores improved (1.4 ± 1.3 s, $p$<.001) and Modified PPT scores improved (2 ± 2 points, $p$<.001) (Table 2).

***Baseline Measures and Change in Measures of Flexed Posture***

Changes in Flexed Posture Following Group Exercise

There were no significant correlations between baseline BMD T-score, ROM, or strength and change in kyphosis (*p*>.05). The number of VCF at baseline did not have a significant effect on the change in kyphosis (*p*>.05). Age at baseline correlated with change in "best" kyphosis (r = .50, *p*=.02); younger participants had greater improvements in "best" kyphosis than older participants. Modified PPT at baseline correlated with change in "usual" and "best" kyphosis (r = -.42, *p*=.055); higher functioning participants had greater improvements in kyphosis.

***Change in Strength or ROM and Change in Flexed Posture***

There were no significant correlations between changes in strength or ROM and change in kyphosis (*p*>.05).

***Change in Measures of Flexed Posture and Change in Physical Performance***

There were no significant correlations between change in measures of flexed posture and change in physical performance (*p*>.05).

**DISCUSSION**

These results support our primary hypothesis that improved flexed posture and improved physical performance would be observed following a 12-week multi-dimensional group exercise in women 65 years and older with flexed posture. The 6° change in "usual" kyphosis represents an 11% improvement and the 5° change in "best" kyphosis represents a 10% improvement from baseline. This exceeded that described by Itoi & Sinaki after a two-year prone trunk extension intervention.[19] It was consistent with that reported from 6-month use of passive postural bracing.[21] This improvement in kyphosis in 12-weeks exceeds the amount of progression of kyphosis typically observed over a decade in older individuals and may have significant longitudinal benefits.

The magnitude of change in trunk extension strength in this study exceeded that reported by other research. To compare our results to others, we converted peak torque/ body weight ratio to peak torque multiplying by body weight. Our results demonstrated a 53% increase in peak torque after three-months in our participants who were 72.0 ± 4.2 years old (mean ± SD). One study reported a 24-45% increase at six months in women 80.2 ± 4.8 years, while another reported a 27% increase at one year in women 35.9 ± 2.9 years.[26 44] While we used the same prone trunk extension strengthening intervention as Gold et al., we developed a multi-dimensional intervention including sensory integration training of postural alignment that may have enhanced our participants' strength. However, the method for testing trunk extension strength was not identical across all studies.

This intervention increased range of motion in the lower extremities. Popliteal angle increased bilaterally to age-matched normative values for this measure.[45] There was no change in shoulder mobility as measured shoulder flexion range of motion. There may be better methods to measure shoulder mobility that quantify pectoral muscle length that can be used in future study.

The 2-point increase in Modified PPT score matched that previously reported in the initial 3-month phase of a group exercise intervention in sedentary adults 83 ± 4 years.[41] There were no significant changes in measures of balance and gait speed. However, our participants were comparable to age-matched normal individuals on the Balance Master SOT and had slower COP velocity than healthy adults age 66-70 years at baseline.[22, 46] Furthermore, our participants were extremely robust with a baseline gait speed of 1.35 m/second.

Changes in Flexed Posture Following Group Exercise

We did find that some characteristics of the women were associated with the amount of change in flexed posture. Younger participants demonstrated greater change in "best" kyphosis consistent with prior findings that younger women have more ability to improve kyphosis compared to older women.[6] Our finding that baseline Modified PPT scores correlated with change in "usual" and "best" kyphosis suggests that higher functioning individuals exhibited greater postural change. We did not find a relationship between the number of vertebral compression fractures and change in flexed posture. In fact, the five women with the greatest number of VCF (three) improved "usual" kyphosis 7.4° and "best" kyphosis 5.5°, results comparable to the group as a whole.

These results did not find that changes in strength or ROM correlated with change in flexed posture. It is possible the strength measurements quantified lumbar extension strength and did not measure the change in thoracic extension strength, which may be associated with improved kyphosis. We expected to find a correlation between improved hamstring flexibility, measured by popliteal angle, and improved kyphosis because improving hamstring flexibility theoretically allows greater mobility in the pelvis and spine. However, we did not measure lumbar lordosis and it is likely that increasing hamstring flexibility allowed the pelvis to rotate into more anterior rotation and increased lumbar lordosis rather than decreased thoracic kyphosis. This may also explain why there was no increase in height as kyphosis improved; an increase in lumbar lordosis would concomitantly reduce standing height equal to any increased height expected from improving kyphosis alone.

These results did not support our third hypothesis that changes in flexed posture correlated with change in physical performance. The measures of flexed posture were static measurements that may not capture the dynamic nature of the physical performance tasks. Our participants were also extremely robust, with normal balance, gait speed and Modified PPT scores at baseline. While there were significant changes in physical performance, small effect sizes may limit the ability to detect significant correlations <.05. Furthermore, other co-variates not measured, such as trunk proprioception, vital capacity, pain, co-morbidities and mobility self-confidence may influence change in kyphosis and physical performance.

The participation rate in the 12-week program was exceptional and demonstrated the appealing and feasible nature of the exercise program. Other than those who withdrew due to unrelated injuries or family emergency, there was 100% adherence to the 24 sessions and the home postural alignment practice.

We recognize our study had several limitations. This study is a single group pre- test posttest design and is not a randomized controlled trial. However, we tried to reduce the confounding effects of measurement variability and learning by comparing our results to the 95% confidence interval of T2-T1 measurements. In all cases we met or exceeded this confidence interval, evidence that T3-T2 change was attributable to the intervention (Table 2). Additionally, we applied the most conservative correction for multiple comparisons in order to reduce the probability of making a type-I error. We enrolled a group of highly motivated, robust women and cannot generalize our results to less-motivated or frail populations. We had a small sample size limiting power to detect significant correlations r<0.5, and restricting analysis of covariates known to affect variation in function from spinal deformity.[47] We did not find significant change in other measures of flexed posture previously reported. [20, 21]

### Changes in Flexed Posture Following Group Exercise

These results provide intriguing preliminary data that this type of exercise intervention may not only improve posture, but also improve physical performance. Further research is needed to develop better methods to quantify standing height and forward head posture that incorporate postural sway and multiple degrees of freedom in the spine, pelvis and legs, as well as to develop dynamic measures of flexed posture during functional activities. During our study, participants expressed improved self-confidence as their posture improved and future work should incorporate measures of body image and quality of life. Ultimately, a randomized controlled trial with a larger sample size and longer-term outcomes would allow optimal analysis of pathways of change between flexed posture, impairments of strength and ROM, and physical performance.

## CONCLUSION

These results demonstrate statistically significant gains can be made in measures of flexed posture, strength, ROM, and physical performance in older women with increased kyphosis. This three-month multi-dimensional exercise intervention yielded greater improvements in kyphosis and spinal extension strength than other techniques have previously reported. Considering kyphosis progresses with age and is associated with decreased physical performance and increased fracture risk, targeted exercise that improves kyphosis may have significant functional implications. Multi-dimensional group exercise should be considered when developing a comprehensive program to improve posture, musculoskeletal impairments and physical performance.

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## REFERENCES

1. Balzini L, Vannucchi L, Benvenuti F, et al. Clinical Characteristics of Flexed Posture in Elderly Women. *J Am Geriatr Soc.* Oct 2003;51(10):1419-1426.
2. Ensrud KE, Black DM, Harris F, et al. Correlates of kyphosis in older women. The Fracture Intervention Trial Research Group. *J Am Geriatr Soc.* Jun 1997;45(6):682-687.
3. Ettinger B, Black DM, Palermo L, et al. Kyphosis in older women and its relation to back pain, disability and osteopenia: the study of osteoporotic fractures. *Osteoporos Int.* Jan 1994;4(1):55-60.
4. Huang MH, Barrett-Connor E, Greendale GA, et al. Hyperkyphotic posture and risk of future osteoporotic fractures: the Rancho Bernardo study. *J Bone Miner Res.* Mar 2006;21(3):419-423.
5. Purser JL, Pieper CF, Duncan PW, et al. Reliability of physical performance tests in four different randomized clinical trials. *Arch Phys Med Rehabil.* May 1999;80(5):557-561.
6. Hinman MR. Comparison of thoracic kyphosis and postural stiffness in younger and older women. *Spine J.* Jul-Aug 2004;4(4):413-417.
7. Lyles KW, Gold DT, Shipp KM, et al. Association of osteoporotic vertebral compression fractures with impaired functional status. *Am J Med.* Jun 1993;94(6):595-601.
8. Lynn SG, Sinaki M, Westerlind KC. Balance characteristics of persons with osteoporosis. *Arch Phys Med Rehabil.* Mar 1997;78(3):273-277.
9. Ryan SD, Fried LP. The impact of kyphosis on daily functioning. *J Am Geriatr Soc.* Dec 1997;45(12):1479-1486.

10. Sinaki M, Brey RH, Hughes CA, et al. Balance disorder and increased risk of falls in osteoporosis and kyphosis: significance of kyphotic posture and muscle strength. *Osteoporos Int.* Aug 2005;16(8):1004-1010.

11. Sinaki M, Itoi E, Rogers JW, et al. Correlation of back extensor strength with thoracic kyphosis and lumbar lordosis in estrogen-deficient women. *Am J Phys Med Rehabil.* Sep-Oct 1996;75(5):370-374.

12. Ferrucci L, Bandinelli S, Cavazzini C, et al. Neurological examination findings to predict limitations in mobility and falls in older persons without a history of neurological disease. *Am J Med.* Jul 15 2004;116(12):807-815.

13. Vandervoort AA. Aging of the human neuromuscular system. *Muscle Nerve.* Jan 2002;25(1):17-25.

14. Schneider DL, von Muhlen D, Barrett-Connor E, et al. Kyphosis does not equal vertebral fractures: the Rancho Bernardo study. *J Rheumatol.* Apr 2004;31(4):747-752.

15. Keller TS, Harrison DE, Colloca CJ, et al. Prediction of osteoporotic spinal deformity. *Spine.* Mar 1 2003;28(5):455-462.

16. Sinaki M, Itoi E, Wahner HW, et al. Stronger back muscles reduce the incidence of vertebral fractures: a prospective 10 year follow-up of postmenopausal women. *Bone.* Jun 2002;30(6):836-841.

17. Sinaki M, Mikkelsen BA. Postmenopausal spinal osteoporosis: flexion versus extension exercises. *Arch Phys Med Rehabil.* Oct 1984;65(10):593-596.

18. Sinaki M, Lynn SG. Reducing the risk of falls through proprioceptive dynamic posture training in osteoporotic women with kyphotic posturing: a randomized pilot study. *Am J Phys Med Rehabil.* Apr 2002;81(4):241-246.

**19.** Itoi E, Sinaki M. Effect of back-strengthening exercise on posture in healthy women 49 to 65 years of age. *Mayo Clin Proc.* Nov 1994;69(11):1054-1059.

**20.** Greendale GA, McDivit A, Carpenter A, et al. Yoga for women with hyperkyphosis: results of a pilot study. *Am J Public Health.* Oct 2002;92(10):1611-1614.

**21.** Pfeifer M, Begerow B, Minne HW. Effects of a new spinal orthosis on posture, trunk strength, and quality of life in women with postmenopausal osteoporosis: a randomized trial. *Am J Phys Med Rehabil.* Mar 2004;83(3):177-186.

**22.** Sinaki M, Brey RH, Hughes CA, et al. Significant reduction in risk of falls and back pain in osteoporotic-kyphotic women through a Spinal Proprioceptive Extension Exercise Dynamic (SPEED) program. *Mayo Clin Proc.* Jul 2005;80(7):849-855.

**23.** Latham NK, Bennett DA, Stretton CM, et al. Systemic review of progressive resistance strength training in older adults. *Journal of Gerontology: Med Sci.* 2004;59A(1):48-61.

**24.** Seguin R, Nelson ME. The benefits of strength training for older adults. *Am J Prev Med.* 2003;25(3Sii):141-149.

**25.** Seynnes O, Fiatarone Singh MA, Hue O, et al. Physiological and functional responses to low-moderate versus high-intensity progressive resistance training in frail elders. *J Gerontol A Biol Sci Med Sci.* May 2004;59(5):503-509.

**26.** Gold DT, Shipp KM, Pieper CF, et al. Group treatment improves trunk strength and psychological status in older women with vertebral fractures: results of a randomized, clinical trial. *J Am Geriatr Soc.* Oct 2004;52(9):1471-1478.

**27.** Patterson RM, Stegink Jansen CW, Hogan HA, et al. Material properties of Thera-Band Tubing. *Phys Ther.* Sep 2001;81(8):1437-1445.

28. Schneider JK, Eveker A, Bronder DR, et al. Exercise training program for older adults. Incentives and disincentives for participation. *J Gerontol Nurs.* Oct 2003;29(9):21-31.

29. Emmons KM, Rollnick S. Motivational interviewing in health care settings. Opportunities and limitations. *Am J Prev Med.* Feb 2001;20(1):68-74.

30. apta.org/consumer/ptandyourbody/osteoporosis.

31. The secrets of good posture. www.apta.org.

32. Home modification and safety. www.homemods.org.

33. Watkins LPM. *Foundations of Clinical Research: Applications to Practice*. 2nd Ed ed. New Jersey: Prentice Hall Health; 2000.

34. Rodacki CL, Fowler NE, Rodacki AL, et al. Technical note: repeatability of measurement in determining stature in sitting and standing postures. *Ergonomics.* Oct 10 2001;44(12):1076-1085.

35. Gajdosik RL, Bohannon RW. Clinical measurement of range of motion. Review of goniometry emphasizing reliability and validity. *Phys Ther.* Dec 1987;67(12):1867-1872.

36. Norkin CW, JD. *Measurement of Joint Motion*. 3rd ed. Philadelphia: F. A. Davis Company; 2003.

37. Kendall HO, Kendall FP. Developing and maintaining good posture. *Phys Ther.* Apr 1968;48(4):319-336.

38. Ford-Smith CD, Wyman JF, Elswick RK, Jr., et al. Test-retest reliability of the sensory organization test in noninstitutionalized older adults. *Arch Phys Med Rehabil.* Jan 1995;76(1):77-81.

39. Du Pasquier RA, Blanc Y, Sinnreich M, et al. The effect of aging on postural stability: a cross sectional and longitudinal study. *Neurophysiol Clin.* Nov 2003;33(5):213-218.

40. Marsh AP, Rejeski WJ, Lang W, et al. Baseline balance and functional decline in older adults with knee pain: the Observational Arthritis Study in Seniors. *J Am Geriatr Soc.* Apr 2003;51(3):331-339.

41. Binder EF, Schechtman KB, Ehsani AA, et al. Effects of exercise training on frailty in community-dwelling older adults: results of a randomized, controlled trial. *J Am Geriatr Soc.* Dec 2002;50(12):1921-1928.

42. Stanziano DC BS, Sandler DJ, Roos BA, et al. The gallon-jug shelf test: a new method of assessing age-dependent changes in the ability to manipulate moderately heavy objects. Paper presented at: AGS 2003 Annual Meeting, 2003.

43. Melton LJ, 3rd, Kan SH, Frye MA, et al. Epidemiology of vertebral fractures in women. *Am J Epidemiol.* May 1989;129(5):1000-1011.

44. Sinaki M, Wahner HW, Bergstralh EJ, et al. Three-year controlled, randomized trial of the effect of dose-specified loading and strengthening exercises on bone mineral density of spine and femur in nonathletic, physically active women. *Bone.* Sep 1996;19(3):233-244.

45. Youdas JW, Krause DA, Hollman JH, et al. The influence of gender and age on hamstring muscle length in healthy adults. *J Orthop Sports Phys Ther.* Apr 2005;35(4):246-252.

46. Prieto TE, Myklebust JB, Hoffmann RG, et al. Measures of postural steadiness: differences between healthy young and elderly adults. *IEEE Trans Biomed Eng.* Sep 1996;43(9):956-966.

**47.** Purser JL, Pieper CF, Branch LG, et al. Spinal deformity and mobility self-confidence among women with osteoporosis and vertebral fractures. *Aging (Milano).* Sep 1999;11(4):235-245.

Table 1. Descriptive Characteristics, Measures of Flexed Posture, Strength, ROM and Physical Performances @ Baseline, N =21

| Characteristics | Mean ± SD (Median) | Range (Min – Max) | ICC |
|---|---|---|---|
| *Descriptive Characteristics* | | | |
| Age (yrs) | 72.0 ± 4.2 | 66 - 80 | NA |
| Vertebral compression fractures (n) | (2) | 0 - 3 | NA |
| BMD (T-score) | -1.5 ± 1.3 | -3.6 – 0.7 | NA |
| *Flexed Posture* | | | |
| Kyphosis – usual (deg) | 57 ± 5.0 | 47 – 65 | .93 |
| Kyphosis – best (deg) | 50 ± 6.0 | 37 - 60 | .94 |
| Forward head – usual (in) | 8.8 ± 0.7 | 7.4 – 10.1 | .76 |
| Forward head – best (in) | 8.4 ± 1.1 | 6.3 – 11.2 | .86 |
| Height – usual (cm) | 160.9 ± 7.7 | 147.5 – 176.3 | .99 |
| Height – best (cm) | 161.8 ± 7.9 | 148.4 – 176.9 | .99 |
| *Strength and ROM* | | | |
| Biodex extension strength (% BW) | 35.2 ± 14.8 | 9.8 – 57.4 | .84 |
| Prone extension (lb) | 17.6 ± 3.8 | 11.3 – 24.3 | .46 |
| Shoulder flexion R (deg) | 162 ± 12.5 | 140 – 180 | .83 |
| Shoulder flexion L (deg) | 159 ± 11.7 | 135 - 176 | .73 |
| Popliteal angle R (deg) | 141 ± 9.2 | 123 - 155 | .85 |

| | | | |
|---|---|---|---|
| Popliteal angle L (deg) | 142 ± 11.0 | 124 - 162 | .67 |
| Modified Thomas Test R (deg) | 27 ± 6.4 | 15 – 37 | .87 |
| Modified Thomas Test L (deg) | 27 ± 6.7 | 13 - 38 | .86 |
| *Physical Performance* | | | |
| Balance Master SOT (100 pt) | 73 ± 8 | 58 - 86 | .75 |
| COP velocity (cm/s) | 1.5 ± 0.7 | .7 – 3.6 | .86 |
| COP excursion (% stance length) | 53.6 ± 7.0 | 38.7 – 67.3 | .79 |
| Modified PPT (36-pt) | 30 ± 2.6 | 25 - 34 | .74 |
| Jug Test (s) | 13.5 ± 3.3 | 8.9 – 22.6 | .92 |
| Gait speed (m/s) | 1.35 ± 0.18 | 1.03 – 1.67 | .92 |

Abbreviations: SD, standard deviation; Min, minimum; Max, maximum, NA, not applicable

ICC = Intraclass Correlation Coefficient (3,1)

Table 2. Differences (T2 – T1) and Change (T3 – T2) in Dependent Measures

| Dependent Measure | T2 - T1 | *p*-value | T3 - T2 | *p*-value |
|---|---|---|---|---|
| *Flexed Posture* | | | | |
| Kyphosis – usual (deg) | 1 (-1,2) | .67 | -6 ± 3 | <.001* |
| Kyphosis – best (deg) | 0 (-2,2) | .99 | -5 ± 3 | <.001* |
| Forward head – usual (in) | 0 (-0.4,0.3) | .99 | -0.1 ± 0.5 | .82 |
| Forward head – best (in) | 0.1 (-0.3,0.5) | .86 | -0.2 ± 0 .7 | .49 |
| Height – usual (cm) | 0.2 (-0.2,0.5) | .50 | 0.2 ± 0.6 | .41 |
| Height – best (cm) | 0.1 (-0.1,0.4) | .26 | 0.1 ± 0.4 | .98 |
| *Strength and ROM* | | | | |
| Biodex extensor strength (%BW) | -4 (-11,4) | .44 | 21 ± 13 | <.001* |
| Prone extension (lb) | 1 (-1,3) | .60 | 1 ± 4 | .75 |
| Shoulder flex R (deg) | 0 (-4,4) | .99 | -0.5 ± 6.4 | .93 |
| Shoulder flex L (deg) | -1 (-6,5) | .93 | 2 ± 10 | .56 |
| Popliteal R (deg) | -1 (-4,3) | .83 | 7 ± 7 | <.001* |
| Popliteal L (deg) | 0 (-5,5) | .99 | 9 ± 10 | <.001* |
| Mod Thomas Test (deg) | 0 (-2,3) | .97 | 4 ± 5 | .003 |
| Mod Thomas Test (deg) | 0 (-3,2) | .91 | 2 ± 6 | .38 |
| *Physical Performance* | | | | |
| Balance Master SOT (100 pt) | 3 (0,6) | .05 | 2 ± 7 | .40 |
| COP velocity (cm/s) | 0.1 (-0.1,0.3) | .45 | -1.0 ± 5 | .77 |
| COP excursion (% stance length) | 0.9 (-3,5) | .81 | -0.07 ± 0.4 | .62 |
| Jug Test (s) | -0.5 (-1.3,0.2) | .21 | -1.4 ± 1.3 | .001* |
| Modified PPT (36-pt) | 1 (0,2) | .23 | 2 ± 2 | .001* |

T1= Time 1 initial measurement; T2 = Time 2 pretest measurement; T3= Time 3 posttest measurement

T2-T1 data reported as mean change (95% confidence interval)

T3-T2 data reported as mean change ± standard deviation

* Significant difference T3 – T2 at $p < 0.025$ (by paired t tests)

Appendix 1. Exercise Intervention

| Exercise | Intensity/Duration | Target |
|---|---|---|
| **Warm-up (5 mins)** | **10 repetitions - active** | |
| Shoulder, chest, upper back ROM | Active range of motion | Increase heart rate before stretch & strengthen exercises |
| **Strengthening (20 mins)** | **3 sets of 8 repetitions, 0 – 5# or theraband®** | |
| Prone trunk lift to neutral | Arms by side → "W" position by shoulders → fists by ears | Thoracic and lumbar spine extension, scapular strengthening |
| Quadruped arm/leg lift | Ankle & wrist cuff weights | Lower trapezius, spinal extension, multifidus and transverses abdominus stabilization |
| Bilateral shoulder flexion | Theraband® resistance | Lower trapezius, spinal extension, multifidus and transverses abdominus stabilization |
| Supine on roller | | |
| Sidelying thoracic rotation | Theraband® resistance | Thoracic extension, rotation strength and mobility |

| | | |
|---|---|---|
| **ROM exercises (15 mins)** | **Passive 30 s hold** | |
| Chest stretching & diaphragmatic breathing, supine on roller | Combine with shoulder flexion exercises | Lengthen pectoralis major; expand ribcage and anterior chest wall |
| Prone hip extension | Passive –stretch strap x 1 bilaterally | Lengthen iliopsoas and quadriceps |
| Supine straight leg raise | Passive –stretch strap x 1 bilaterally | Lengthen hamstrings and gastroc-soleus |
| Quadruped thoracic extension/chest stretch | Passive – x 3 | Increase thoracic spine extension and lengthen anterior chest wall musculature |
| **Postural Alignment (15 mins)** | **Active** | |
| Postural correction | Standing, eyes open, eyes closed | Recognition and integration of sensory cues for correct alignment |
| Neutral spine sit → stand | Seated on gym ball – 10 repetitions | Recognition and integration of correct sensory cues during functional activities |
| **Cool-down (5 mins)** | **Active** | |
| Wall push-ups | Body weight as resistance x 10 | Scapular stabilization |
| Overhead arm wall slides | Lift arms from wall end range x 10 | Lower trapezius muscles |
| Calf stretching at wall | Passive 30 s hold x 1 | Gastroc-soleus muscles |
| **Home Postural Alignment** | Postural correction at | Integrate improved postural |