Back Muscle Function in Older Women With Age-Related Hyperkyphosis: A Comparative Study

Tayebeh Roghani, PhD,[a,b] Minoo Khalkhali Zavieh, PhD,[b] Saeed Talebian[c]
Alireza Akbarzadeh Baghban, PhD,[d] and Wendy Katzman, PhD[e]

ABSTRACT

Objective: The purpose of this study was to compare static maximal back extensor muscle force, endurance, and characteristics of flexion relaxation phenomenon (FRP) in older women with and without age-related hyperkyphosis.

Methods: Maximum back extensor force and endurance measured in a sitting position with a designed load cell setup; appearance, onset, and offset angles of FRP; and extension relaxation ratio (ERR) during a dynamic flexion-extension task were compared between 24 older women with hyperkyphosis (thoracic kyphosis angle $\geq 50°$), mean age 65 ± 4.4 years, and 24 older women without hyperkyphosis (thoracic kyphosis angle $\ll 50°$), mean age 63 ± 4.3 years. Variables of force, endurance, angles of FRP, and ERR were analyzed using an independent sample *t* test. A χ^2 test was used to identify differences between groups in FRP appearance.

Results: Static back extensor force and endurance were significantly lower among those with versus those without hyperkyphosis ($P \ll .001$). Although the 2 groups did not differ in FRP appearance and ERR in the superficial erector spinal muscles ($P \gg .05$), FRP in the hyperkyphosis group started sooner and ended later than in the group without hyperkyphosis ($P \ll .05$).

Conclusion: Our study indicates that women with age-related hyperkyphosis had decreased static maximal force and endurance of the back extensor muscles and prolonged myoelectrical silence of the superficial erector spinal muscles. Reduced endurance of the superficial erector spinal muscles may trigger early onset of FRP and prolonged relaxation of these muscles. (J Manipulative Physiol Ther 2019;42:284-294)

Key Indexing Terms: *Kyphosis; Posture; Back Muscles; Muscle Strength; Physical Endurance*

[a] Musculoskeletal Research Center, Rehabilitation Research Institute and Department of Physical Therapy, Faculty of Rehabilitation Sciences, Isfahan University of Medical Sciences, Isfahan, Iran.
[b] Department of Physiotherapy, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
[c] Department of Physiotherapy, School of Rehabilitation, Tehran University of Medical Sciences and Health Services, Tehran, Iran.
[d] Proteomics Research Center, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
[e] Department of Physical Therapy and Rehabilitation Sciences, University of California, San Francisco, California.
Corresponding author: Minoo Khalkhali Zavieh, PhD, Department of Physiotherapy, School of Rehabilitation, Shahid Beheshti University of Medical Sciences, Damavand Aven, across from Bo-Ali Hospital, Tehran, Iran Tel.: +98 21 77561721. (e-mail: *m.khalkhali@sbmu.ac.ir*).
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INTRODUCTION

Age-related hyperkyphosis is an abnormal forward curvature in the thoracic region of the spine.[1] Among age-related postural deformities, accentuated kyphosis is the most common and affects up to 40% of older adults.[2] Thoracic kyphosis increases with age, but there is no uniformly accepted threshold for defining age-related hyperkyphosis.[1] Although Cobb angle measurement from lateral spine radiograph is the current gold standard for quantifying thoracic kyphosis,[3] several noninvasive skin-surface methods have been used for clinical measurement.[4] Although age-related hyperkyphosis affects both sexes, the condition increases at a higher rate in women, particularly during the menopause years, when compared with men.[5] Known complications of hyperkyphosis include poor pulmonary function,[6] loss of physical performance,[2] and increased risk of fracture,[7] which all have a negative impact on the quality of life in older adults.[8] In addition, women with hyperkyphosis experience a higher incidence of adverse health conditions and earlier mortality.[9]

Although there are several complications that can arise in older women with age-related hyperkyphosis, health care providers have only recently started to attend to this condition as a major health concern.[10] Despite numerous studies, the etiology of age-related hyperkyphosis is not full elucidated.[11] Associations among bone mineral density, vertebral fracture, and thoracic kyphosis have been reported,[12] although approximately 60% of the most severe cases of hyperkyphosis have no evidence of underlying vertebral compression fracture.[13] Numerous studies reported a negative correlation between back extensor muscle force and thoracic kyphosis in older women,[14-16] and targeted spinal strengthening exercises reduced thoracic kyphosis angle in older adults.[17] However, from a biomechanical view, trunk muscle endurance may be more important for spinal stabilization than strength[18] because prolonged activation of back extensor muscles is needed to control postural alignment during activities of daily living.[19] However, back extensor endurance has not been well defined in age-related hyperkyphosis, and previous studies focus primarily on the assessment of back extensor force or strength.

A significant decrease of electromyography (EMG) recording of superficial back extensor muscle activation has been reported during slumped sitting[20,21] and forward bending,[22,23] also described as the flexion relaxation phenomenon (FRP).[24] The superficial spinal extensor muscles relax and load shifts to the dorsal passive stabilizers[24] and the deep erector spinal muscles.[25] Similar to slumped sitting, decreased activity of the spinal extensor muscles from prolonged poor habitual postures associated with hyperkyphosis could result in deconditioning, structural and histomorphologic changes, disuse atrophy, and fatty infiltration that finally leads to a loss of strength and endurance of spinal stabilizers.[26,27] However, no studies have examined FRP of the thoracic and lumbar erector spinal muscles in an affected population with age-related hyperkyphosis.

The investigation of back extensor muscle force, endurance, and electrical activity of the muscles using surface EMG may help us understand relaxation occurrence in back extensor muscles in older women with hyperkyphosis. Therefore, our aim was to compare maximal back extensor muscle force and endurance in older women with and without thoracic hyperkyphosis posture. The EMG activity patterns of the superficial erector spinal muscles during a dynamic trunk flexion-extension task were also compared between the 2 groups.

Methods

Participants and Experimental Design

Forty-eight healthy, community-based older women participated in this comparative study. Participants were recruited from multiple locations through advertisements at urban entertainment districts. Inclusion criteria were 60 to 80 years old, body mass index ≤ 33 kg/m^2, and ability to stand and walk independently and without an assistive device. Exclusion criteria included hyperkyphosis posture from childhood; history of current back pain or back pain requiring medical attention in past year; serious trauma leading to fracture or dislocation of spine; prior surgery to the vertebral column or lower extremities in the last year; spinal deformities (including scoliosis, kyphoscoliosis, and tuberculosis); high blood pressure ($\geq$150/90); angina pectoris; rheumatologic conditions; any neurologic defects; spinal malignancy; and use of medications over prior 12 months that could affect muscle performance, the central nervous system, or equilibrium. Eligible women were assigned at enrollment to either a hyperkyphosis group (n = 24) or normal group (n = 24) based upon measurement of kyphosis using the Spinal Mouse. The reliability of this device has been previously reported.[28,29] Hyperkyphosis was defined as thoracic kyphosis $\geq 50°$,[14,30] which has been defined as 1 standard deviation above age-matched normative values.[31] The study was approved by the ethical committee of Shahid Beheshti University of Medical Sciences (Tehran, Iran) (ethical committee number: 93617). Before participation, each participant signed a written informed consent.

Measurement of Static Back Extensor Muscle Force and Endurance

We tested participants in a seated position using a pulling force setup: an S-shaped load cell (H3-C3-100kg-3B-D55, Zemic, China) attached on a vertical bar for isometric force and endurance (Fig 1A and 1B). The setup showed very high reliability (intraclass correlation coefficient $\gg$0.95, standard error of measurement $\ll$1.5, minimal detectable change $\ll$ 4) for isometric back extensor muscle force and high reliability (intraclass correlation coefficient $\gg$0.80, standard error of measurement $\ll$28 seconds, minimal detectable change $\ll$75 seconds) for back endurance measurements, respectively, in older women with and without hyperkyphosis[32] Participants were instructed to sit on a stool with hips and knees flexed to 90°, thighs parallel to the seat[16] and arms crossed on the abdomen while facing the load cell fixed on a vertical bar. Abdominal and pelvic restraints were placed over the abdomen and secured to the back support of the stool. Another strap (thigh restraint) was placed over the top of the thighs[33] at the level of anterior superior iliac spine and tightened to prevent any vertical or forward movement of the thighs or pelvis during the test. After positioning the participant in neutral upright sitting, the load cell was moved vertically on the bar and aligned with the superior border of the manubrium in midline. Four inflexible ropes were shortened individually according to participant-vertical bar distance and participant height, and were connected to the

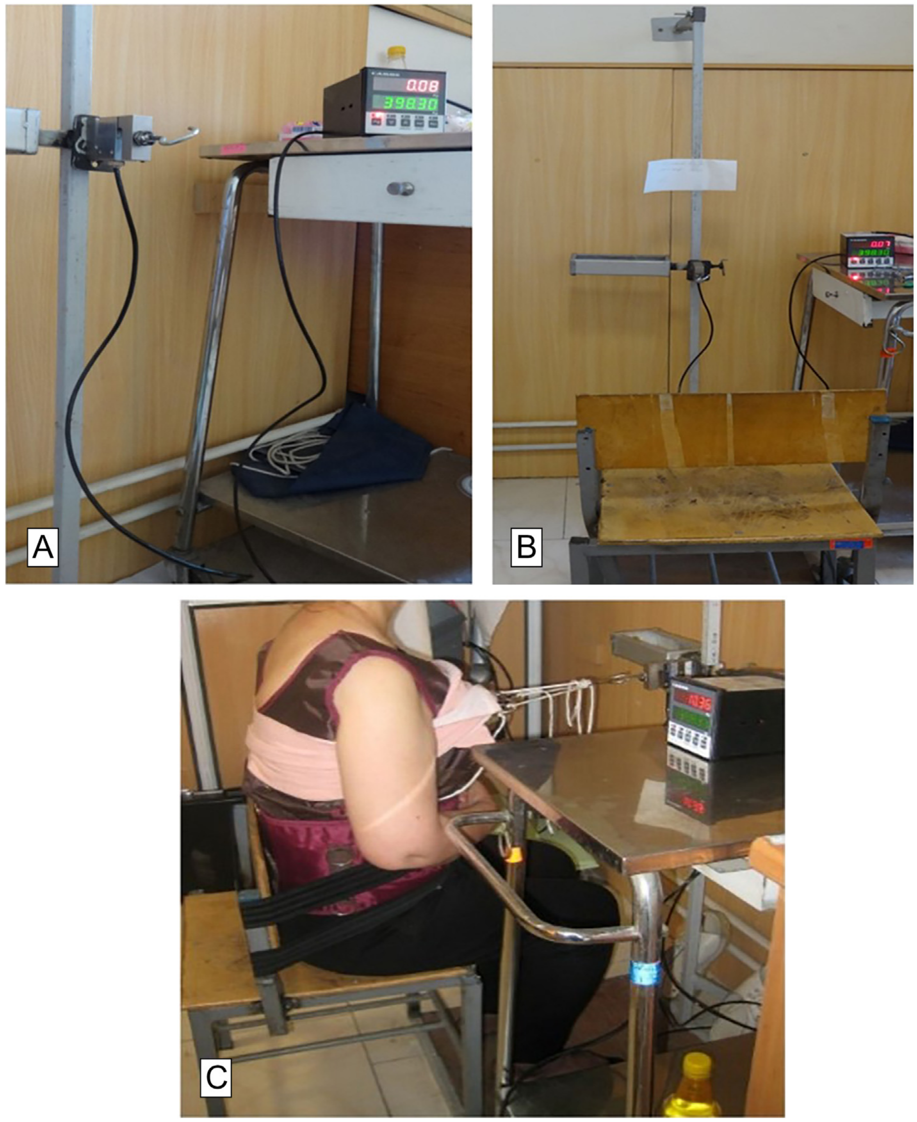


Fig 1. *Pulling apparatus setup. (A, B) S-shaped load cell attached on vertical bar for isometric force and endurance measurements. (C) Apparatus to assess maximum static back extensor force in sitting. The load cell is aligned with the midline, superior border of the manubrium, and participant pulls trunk back maximally.*

load cell hook and fixed to rings of the vest. Participants were instructed to increase backward force and maintain maximal force over 5 seconds (Fig 1C). Each participant was allowed 1 warm-up trial followed by 3 successive maximum effort trials separated by 60-second rest periods.[16] The force generated was processed by an electronic measuring device and converted to a digital display. The maximum force was documented (kg). For the endurance measurement, participants performed a sustained contraction at 50% of the maximum force as their target. When the force could no longer be maintained above 90% of the target level, the test was stopped.[34] After verbal instruction and 1 warm-up trial, 3 endurance trials, separated by 30 seconds of rest, were performed and maximum time was recorded.

During the 2 force and endurance tests, participants received verbal and visual feedback on the digital display to achieve maximum force and maintain the sustained contraction at the target force, respectively. All test procedures were standardized, and the setup was calibrated before testing.

EMG Recording

Instrumentation. Myoelectric activity of thoracic and lumbar erector spinal muscles was recorded with a surface EMG device (DataLOG P3X8, Biometrics Ltd, United Kingdom). Bipolar differential EMG sensors (SX230, Biometrics Ltd, United Kingdom) that have integral electrodes with a fixed electrode distance of 20 mm were applied bilaterally over the thoracic (5 cm lateral to the T9 spinous process)[21,23] and lumbar (4 cm lateral to L3-L4 level)[35] erector spinal muscles. The sensors were positioned in the direction of the muscle fibers. Sensors were taped securely to avoid excessive movement of the leads. A reference electrode was taped on the left wrist.

The EMG signals were amplified by 1000 with a frequency band pass of 10 to 500 Hz, gain 1 μv/Div, signal to noise 80 dB, and CMRR of 110 dB. The sampling rate of recording was 1000 Hz. Thoracic inclination and lumbar flexion angles were recorded simultaneously with 2 electrogoniometers with a sampling rate of 1000 Hz. For lumbar flexion estimation, an electrogoniometer (SG150B, Biometrics Ltd, United Kingdom) was placed at T12/L1 and S1.[36] For thoracic inclination estimation, a second electrogoniometer (SG110, Biometrics Ltd, United Kingdom) was attached at the lower palpable edge of the rib cage[37,38] and parallel to the lower block at the midaxillary line.

Protocol for Testing Flexion Relaxation Response. Before electrode attachment, the skin was shaved and cleaned with cotton presoaked in soapy water. The electrodes and electrogoniometers were placed as described earlier and a signal check was performed to ensure quality EMG signals. During data collection, standing flexion task began with participants in a quiet standing position, feet positioned shoulder width apart, arms relaxed, and wrists lightly clasped in front of the body. This posture was maintained for 5 seconds (phase 1). Participants were then instructed to bend as far forward as possible with knees extended; they were given 3 seconds to reach full flexion (phase 2). The fully flexed position was then held for 5 seconds (phase 3). Participants re-extended to the starting position, reaching quiet standing for 3 seconds (phase 4). Three trials were repeated 30 seconds apart, and the mean value was used for analysis of each phase. Pace was controlled by a digital metronome. Participants were given practice trials before data collection.

Data Processing. The EMG data were full-wave rectified and low-pass filtered using a fourth-order Butterworth filter to form linear envelopes. The reduction of myoelectric activity of superficial erector spinal muscles at the end range of lumbopelvic flexion was defined as flexion relaxation response. The appearance of FRP was defined as the presence or absence of decreased muscular activity in target muscles and was quantified using the extension relaxation ratio (ERR). The ERR was calculated by dividing the maximum of EMG activity during phase 4 by the average EMG activity in phase 3. Using the inverse of this criterion, a threshold ratio of $\ll$40% was used to determine the presence of myoelectric quiescence.[23,39]

The angle at which the EMG onset and offset occurred was determined by 2 synchronized electrogoniometers. The flexion angle, corresponding to the inversed ERR $\ll$40%, was defined as the onset angle. The extension angle, corresponding to inversed ERR $\gg$40%, was defined as the offset angle.[39] For standardization across participants, onset and offset angles were expressed as percentage of both maximum lumbar flexion and maximum thoracic inclination measured using electrogoniometers.

Statistical Analysis

Normality of distribution for all variables was determined using the Shapiro-Wilk test in both groups, and assumption of equality of variance was assessed using Levene's test. Because the 2 assumptions (normality of distribution and equality of variance) were confirmed ($P \gg .05$), we used an independent sample t test for comparison of variables between the 2 groups.

Demographic characteristics were assessed between the 2 groups using an independent sample t test. Also, an independent sample t test was used to test a difference between the 2 groups in static back extensor muscle force and endurance. A χ^2 test was used to identify differences between groups in appearance of FRP. For this analysis, the assumption of at least 5 frequency counts per cell in the contingency table was required and confirmed. An independent sample t test was performed to identify the difference of normalized onset and offset angles and ERR between the 2 groups.

A formula for the comparison of the mean of the 2 groups was used to extract statistical parameters (mean, standard deviation) of dependent variables from similar studies.[40-42] According to α = 0.05, ß = 0.01, and power 90%, a sample size of 21 for each group was estimated. To allow for sampling error and dropout, we enrolled 24 participants for each group.

For all statistical tests, a significance level of .05 was used. All analyses were performed with SPSS statistical software, version 16.0 (SPSS, Inc, Chicago, Illinois).

Results

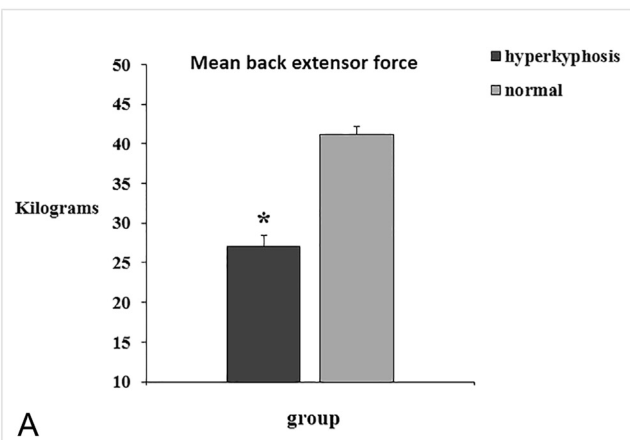
The study sample included 2 groups of healthy, community-dwelling older women, 24 with hyperkyphosis (mean kyphosis: 54° ± 2.3°) and 24 normal group (mean kyphosis: 40° ± 2.4°) (t = 20.83, $P \ll .001$). Body weight (t = 5.13, $P \ll .001$) and body mass index (t = 3.76, P = 0.001) were significantly higher in the hyperkyphosis group compared with the normal group (Table 1). Static back extensor muscle force (t = -8.33) and endurance (t = -5.36) were significantly lower in the hyperkyphosis group compared with the normal group ($P \ll .001$) (Fig 2A and 2B).

There were no significant differences between the 2 groups in appearance of FRP and mean ERR (of left [t = -0.52] and right [t = 1.15] thoracic and of left [t= -0.63] and right [t = 0.04] lumbar erector spinal) in each of the 4 muscles ($P \gg .05$) (Table 2). Figure 3 shows a typical

Table 1. *Participant Characteristics (Mean ± SD)*

Variables	Hyperkyphosis Group (n = 24)	Normal Group (n = 24)	*P* Value [a]
Age (y)	65 ± 4.4	63 ± 4.3	.07
Height (cm)	156 ± 4.5	154 ± 5.3	.07
Weight (kg)	67.8 ± 7.5	59 ± 3.8	**≪.001**
BMI (kg/m^2)	27.9 ± 2.9	24.94 ± 1.8	**.001**
Thoracic kyphosis (°)	54 ± 2.3	40 ± 2.4	**≪.001**
Lumbar lordosis (°)	-35 ± 7.3	-31.62 ± 9	.15

BMI, body mass index.
[a] *P* value of independent *t* test. Bold indicates significant difference between the 2 groups at a significance level of .05.



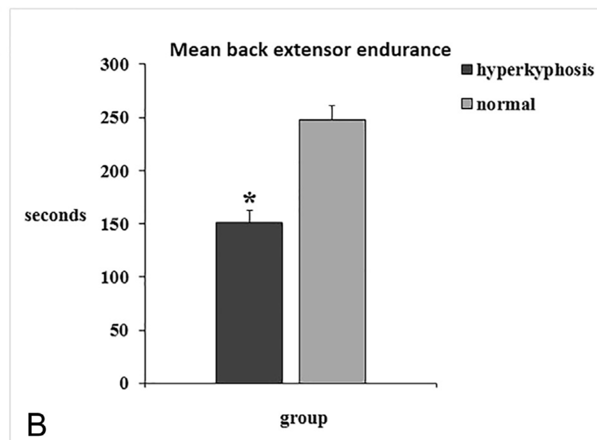


Fig 2. *Static back extensor measurements. (A) Back extensor force; (B) back extensor endurance.* *P ≪ *.05.*

recording of EMG during dynamic trunk flexion-extension task as described in the protocol.

However, in the hyperkyphosis group, the FRP onset and offset angles for thoracic erector spinal muscles were significantly lower than the normal group. The FRP onset and offset angles for lumbar erector spinal muscles were not significantly different than the normal group (Fig 4A-4D) (Table 3).

Discussion

Results from our study demonstrate that static back extensor force and endurance generated by the older women with hyperkyphosis were significantly lower than in those without hyperkyphosis. Although the 2 groups did not differ in FRP appearance and ERR in the superficial erector spinal muscles, these muscles turned off sooner and turned on later in the group with hyperkyphosis, indicating that this silence period was prolonged in the hyperkyphosis group.

Our results are consistent with previous studies demonstrating decreased back extensor force in older women with hyperkyphosis posture.[30,43] Although some authors suggest that this weakness may be part of an overall aging syndrome,[8,44] other studies showed a specific effect in the back extensor muscles[45] that could be caused by prolonged stretch to the back extensors. Sinaki et al categorized women 40 to 80 years old into 4 age groups (40-59, 60-69, 70-79, and 80 and older) and compared back extensor and grip strength in each age group according to healthy or osteoporotic status. Back extensor muscle strength differed according to health status but not age, and grip strength was different only in those 70 to 79 years old.[45] Moreover, the association between greater thoracic kyphosis and lower back extensor force reported in adolescents[46] suggests that we cannot attribute this decrease in back extensor force to the general weakening process of aging syndrome.

To our knowledge, this study is the first to investigate and report differences in spinal extensor endurance in older women with and without hyperkyphosis. Our results of lower endurance generated by the older women with hyperkyphosis are consistent with previous studies in other ages[19,47,48] that reported association between back muscle

Table 2. *Comparison of FRP Appearance and ERR Between the 2 Groups*

Muscle	Frequency of FRP (%) in Hyperkyphosis Group	Frequency of FRP (%) in Normal Group	*P* Value [a]	ERR in Hyperkyphosis Group (Mean ± SD)	ERR in Normal Group (Mean ± SD)	*P* Value [b]
TESL	62.5	70.83	.54	9 ± 1.6	6.8 ± 5.5	.60
LESL	54.16	66.66	.37	10.75 ± 8.8	6.9 ± 5.4	.53
TESR	58.33	75	.22	15 ± 6.8	6.2 ± 4.4	.25
LESR	54.16	70.83	.23	12.6 ± 9.2	12.24 ± 10.5	.96

ERR, extension relaxation ratio; *FRP*, flexion relaxation phenomenon; *LESL*, left lumbar erector spinal muscle; *LESR*, right lumbar erector spinal muscle; *TESL*, left thoracic erector spinal muscle; *TESR*, right thoracic erector spinal muscle.
[a] *P* value of χ^2 test.
[b] *P* value of independent *t* test.

endurance and posture, although none of the participants were selected for hyperkyphosis posture. One study examined the effect of changing head and neck posture on low back muscle endurance in a sample of 117 healthy children. Each participant performed the Biering-Sorensen test in 3 head and neck positions (neutral, flexed, and extended). The extended position was associated with the highest endurance scores, followed by a neutral position and flexed position. Similar to hyperkyphosis where the thoracic spine is excessively flexed, adopting a flexed cervical posture may compromise spinal extensor endurance and increase risk of impairment.[49]

Flexion relaxation phenomenon appearance was not significantly different between the 2 groups; however, FRP appearance was lower than previous studies of younger adults.[22,27,50] In older adults during trunk forward bending, the amount of lumbar flexion decreases and pelvic rotation increases to compensate.[51] In comparison to younger adults during a similar task, lumbar flexion and dorsal passive strain and tension are lower. Active tissues may need to compensate for this decreased participation of passive stabilizers for motor control of the spine. Furthermore, older adults compared with younger adults rely less on spinal reflexes and associate more with control at the supraspinal levels (greater cortical activation and cortical disinhibition).[52] This reorganization may underlie the increased coactivation strategy in the elderly as evidenced by Grieg et al that in contrast to younger adults, arm flexion task was associated with co-contraction of trunk flexor and extensor muscles.[53] Further investigations of changes in motor control with aging are needed.

Flexion relaxation phenomenon in the superficial erector spinal muscles of the hyperkyphosis group was started sooner and ended later, which indicated a prolonged relaxation period of these muscles during the dynamic flexion-extension task in the hyperkyphotic women. This prolonged relaxation period, or silence, is consistent with decreased measured endurance in the back extensor muscles of the hyperkyphosis group. Normal posture during daily activities requires proper load shifting between the stabilizing tissues of the spine, good muscular recruitment, and a coordinated interaction between muscles for normal motor control.[54] In the hyperkyphosis group, the reduced endurance of active stabilizers may compromise load sharing between the muscle and viscoelastic elements and trigger the prolonged silence period. Similar results were reported by Nimbarte et al, who investigated FRP of cervical erector spinal muscles pre- and post-fatigue using neutral and shrugged shoulder postures in 13 healthy younger men. Flexion relaxation phenomenon of cervical erector spinal muscles was observed only in neutral shoulder position pre- and post-fatigue. In neutral position during flexion, the fatigued muscles turned off sooner and during extension turned on later.[39] On the other hand, prolonged flexed postures are associated with loss of muscle activation of back extensor muscles,[47] which may result in damage to the O2 transport,[22] deconditioning,[47] and endurance impairment of these muscles. Longitudinal studies are required to determine the cause and effect relationship between back muscle endurance and posture.

This prolonged silence period in the group with hyperkyphosis is in contrast to previous studies about creep that caused delayed cessation and early activation of the active tissues.[35,55] Induced creep has been shown to reduce FRP duration (later onset), which suggests that back extensor muscles are required to generate more active forces to compensate for the reduced contribution of creep-deformed passive tissues during full-trunk flexion. These studies investigated the effect of short-term cervical[56] and lumbar[35,55] postures in healthy and younger participations, and motor control of the spine can be different in various conditions.[20] When the central nervous system encounters laxity initially, it has to rely more on the active component of the control system,[38] whereas in a chronic age-related flexed posture with active insufficiency of the back extensor muscles, reduced muscular recruitment of the active stabilizers of the spine may result in reliance of the central nervous system on passive tissues. Future studies of motor control of the spine in older women with hyperkyphosis are needed to understand these differences.

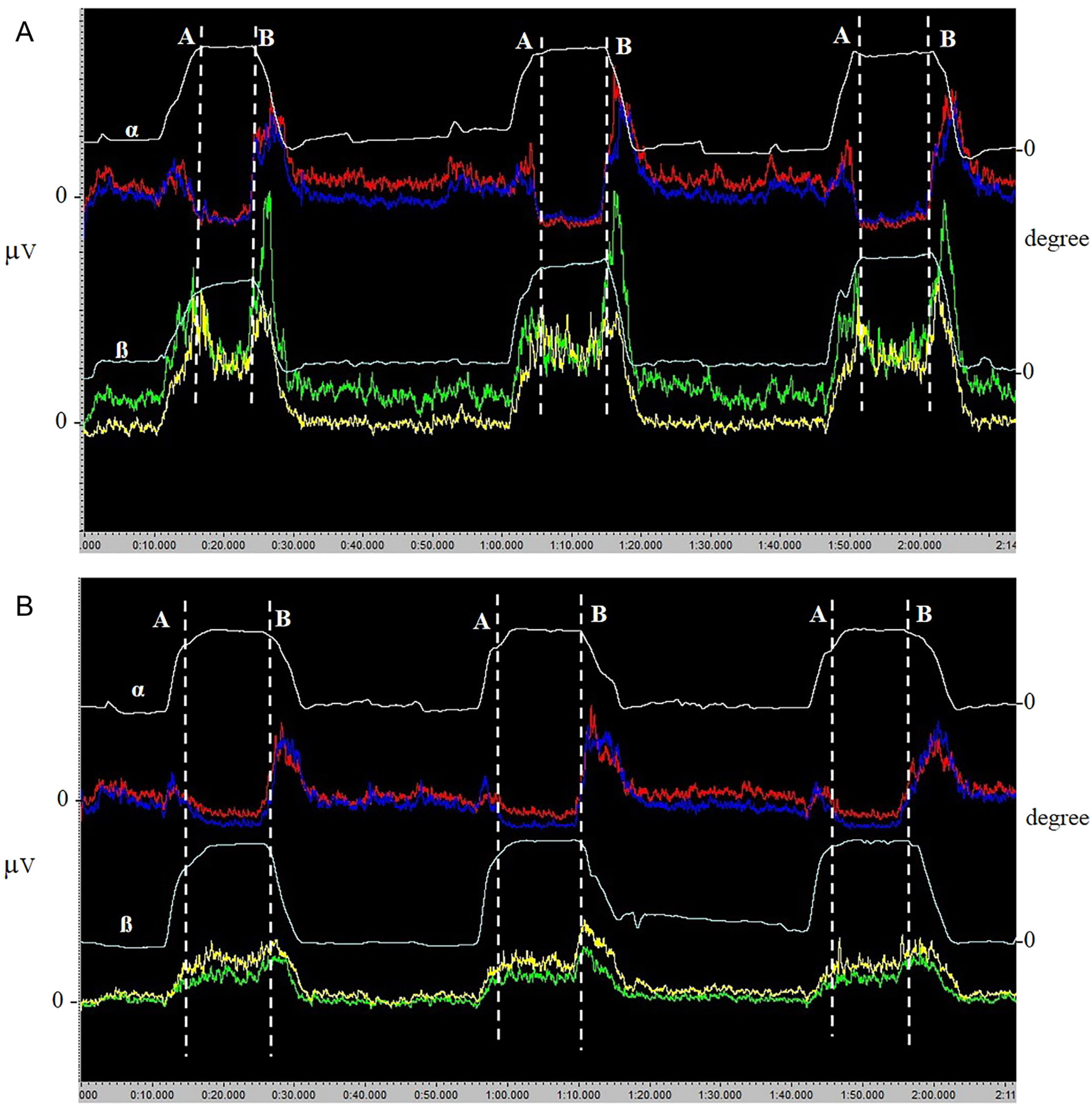


Fig 3. *Typical recording of EMG activity during flexion–extension. (A) Normal group. (B) Hyperkyphosis group. White traces show thoracic inclination (α) and lumbar flexion (ß). (A) EMG off, and (B) EMG on. The top 2 colored traces (red and blue) show the EMG activity of thoracic erector spinal muscles, and the lower colored traces (green and yellow) show the EMG activity of lumbar erector spinal muscles.* EMG, *electromyography.*

We found no difference between groups in the mean ERRs. It appears that greater magnitude of thoracic kyphosis does not influence the amplitude of activity of erector spinal muscles during a dynamic task, but it has the potential to interfere with neuromuscular control through a change in timing of the muscular activity pattern. Similarly, during forward arm movement, Grieg et al reported earlier onset of the thoracic and lumbar erector spinal muscles in the high kyphosis group (greater than 40°) compared with the low kyphosis group (less than 40°), although the mean muscle activity was not significantly different between groups.[53]

In contrast to the findings in the thoracic spine, there was no statistically significant difference in the angles of FRP onset and offset in the lumbar spine. The angles of FRP are associated with the range of lumbar flexion,[57] and the lordosis angle and lumbar flexion range were not different between the 2 groups. The observed difference in muscle activation patterns in the thoracic versus the lumbar spine

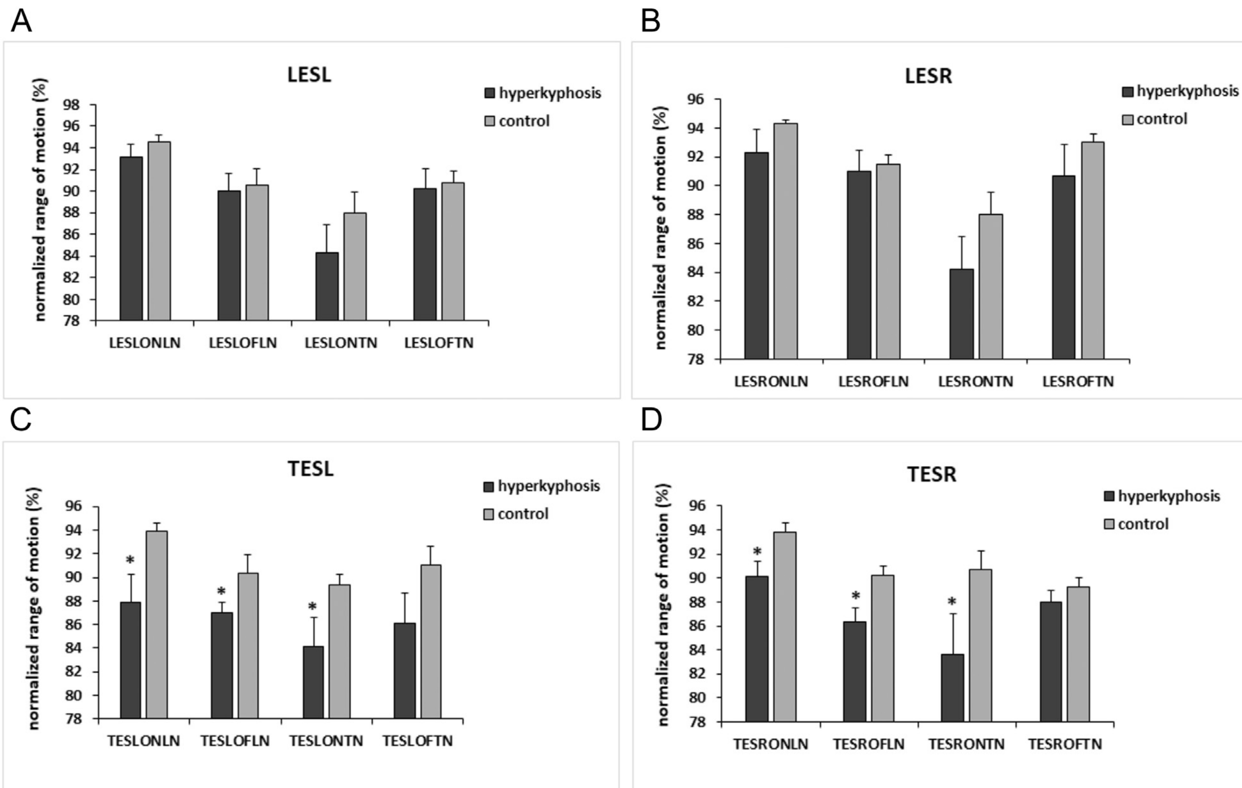


Fig 4. *Onset and offset angles of flexion relation phenomenon in both groups. (A) Left lumbar erector spinal muscle; (B) right lumbar erector spinal muscle; (C) left thoracic erector spinal muscle; (D) right thoracic erector spinal muscle.* * $P \ll .05$. LESL, *left lumbar erector spinal muscle;* LESR, *right lumbar erector spinal muscle;* OFL, *offset according to lumbar goniometer;* OFT, *offset according to thoracic goniometer;* ONL, *onset according to lumbar goniometer;* ONT, *onset according to thoracic goniometer;* TESL, *left thoracic erector spinal muscle;* TESR, *right thoracic erector spinal muscle.*

may be due to biomechanical factors such as undifferentiated lumbar curvature and mobility between the groups[58,59] or a compensatory response for changed motor control of the thoracic region in the hyperkyphosis group.

Strengths and Limitations

This is the first study to compare static back extensor endurance and surface EMG muscle activity pattern during a flexion-extension task in older women with and without hyperkyphosis.

There were several limitations. First, there are no uniformly accepted thresholds for defining age-related hyperkyphosis, and we used a common 50° cutoff to determine the presence of hyperkyphosis. Moreover, we used Spinal Mouse measurement that represents the spinal curvature throughout the thoracic spine whereas others have used radiographic Cobb angle of kyphosis representing the curvature from T4-T12. Although the concurrent validity between these measurements is not known, owing to minimal subcutaneous tissue in the thoracic region, there may be differences in kyphosis values for spinal mouse and radiographic kyphosis measurements. Second, we did not assess physical activity, which could have influenced muscle endurance and strength in our participants. Third, we investigated the muscular pattern of the superficial erector spinal muscles only, and future studies should include the deep muscles. Fourth, age-related changes of both lumbopelvic rhythm and trunk muscular coactivation may have affected the results, but we were unable to record from erector spinal, hip extensor, and abdominal muscles and electrogoniometers simultaneously. Future studies that include simultaneous measurement of EMG from the flexor and extensor muscle groups would provide more complete information about FRP appearance.

Conclusion

This study showed age-related hyperkyphosis is associated with decreased static maximal force and endurance of the back extensor muscles and prolonged myoelectrical silence of the superficial erector spinal muscles. These results help to elucidate the role of the back extensor muscles in age-related hyperkyphosis; however, prospective studies are needed to understand the causal pathways for development of

Table 3. *Comparison of Timing Variables of FRP Between the 2 Groups*

Muscle	Hyperkyphosis Group	Normal Group	t Value	*P* Value [a]
Thoracic level				
TESLONLN	87.85 ± 9.44	93.87 ± 2.90	-2.37	**.03**
TESLOFLN	88.25 ± 3.50	89.30 ± 6.45	-0.58	**.04**
TESLONTN	84.12 ± 9.30	89.37 ± 3.50	-1.99	**.04**
TESLOFTN	86.11 ± 9.60	91 ± 6.60	-1.70	.10
TESRONLN	90.15 ± 4.74	93.80 ± 3.23	-2.56	**.01**
TESROFLN	86.30 ± 4.54	90.27 ± 3.20	-2.91	**≪.01**
TESRONTN	83.60 ± 12.34	90.67 ± 6.70	-2.05	**.04**
TESROFTN	88 ± 3.50	89.22 ± 3.50	-0.95	.34
Lumbar level				
LESLONLN	93.11 ± 4.40	94.50 ± 2.83	-1	.30
LESLOFLN	90 ± 5.90	90.52 ± 6.13	-0.22	.80
LESLONTN	84.30 ± 8.85	87.96 ± 7.60	-1.17	.25
LESLOFTN	90.20 ± 6.40	90.90 ± 4.05	-0.34	.70
LESRONLN	92.30 ± 5.80	94.32 ± 1.22	-1.24	.23
LESROFLN	91 ± 5.50	91.52 ± 2.72	-0.25	.79
LESRONTN	84.22 ± 7.88	89.50 ± 6.35	-1.99	.06
LESROFTN	90.70 ± 7.50	93.64 ± 2.34	-1.33	.21

LESL, left lumbar erector spinal muscle; *LESR*, right lumbar erector spinal muscle; *OFL*, offset according to lumbar goniometer; *OFT*, offset according to thoracic goniometer; *ONL*, onset according to lumbar goniometer, *ONT*, onset according to thoracic goniometer; *TESL*, left thoracic erector spinal muscle; *TESR*, right thoracic erector spinal muscle.

[a] *P* value of independent *t* test. Bold indicates significant difference between the 2 groups at a significance level of .05.

hyperkyphosis. Future studies exploring the electrical activity of back extensor muscles during other static and dynamic conditions in older men and women will help define the role of these muscles in age-related hyperkyphosis.

Funding Sources and Conflicts of Interest

No funding sources or conflicts of interest were reported for this study.

Contributorship Information

Concept development (provided idea for the research): T.R., M.K.Z., S.T., W.K.
Design (planned the methods to generate the results): T.R., S.T.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): W.K.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): T.R., M.K.Z., A.A.B.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): T.R., S.T., A.A.B.
Literature search (performed the literature search): T.R., S.T., W.K.
Writing (responsible for writing a substantive part of the manuscript): T.R., M.K.Z., A.A.B., W.K.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): T.R., M.K.Z., S.T., A.A.B., W.K.

Practical Applications

- Age-related hyperkyphosis is associated with decreased static maximal force and endurance of the back extensor muscles.
- During a dynamic flexion-extension task, there was prolonged silence of the superficial erector spinae muscles in the group with hyperkyphosis compared with the group without hyperkyphosis.
- There was an association between reduced endurance of the back muscles and prolonged silence of the superficial erector spinae muscles during the dynamic activity.
- Future investigation the electrical activity of back extensor muscles during different conditions will help define the role of these muscles in age-related hyperkyphosis.

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