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Original Article

Change in kyphosis does not affect the risk of falling in postmenopausal osteopenic and osteoporotic women

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Abstract

Objectives: To examine the influence of the annual change in kyphosis on the risk of falling in postmenopausal osteopenic and osteoporotic women. **Methods**: This prospective observational study included 498 postmenopausal Greek women over the age of 50, suffering from either osteoporosis or osteopenia. Data on age, height, weight, and self-reported falls were collected. Additionally, we evaluated the degree of the kyphosis angle, the balance, the mobility, the functionality and the handgrip strength on both hands of each subject using the Debrunner kyphometer, the Berg Balance Scale, the Timed-Up-and-Go test, the 30 Seconds Sit-to-Stand test and the Jamar Hydraulic Hand Dynamometer, respectively. All the above data were recorded at the baseline visit and the 12-month follow-up visit for each participant. **Results**: All examined variables presented a statistically significant change at the 12-month follow-up visit. Nevertheless, the annual change in kyphosis did not show any association with the risk of falling. **Conclusion**: No association was shown between the annual change in kyphosis and the risk of falling in postmenopausal osteopenic and osteoporotic women, nor bears any substantial prognostic value for future falls.

Keywords: Fall Risk, Kyphometer, Kyphosis, Kyphotic Angle Change, Postmenopause

Introduction

Kyphosis is outlined as the expected yet average curvature that can be located in the spinal column's thoracic segment and is characterized by a modest anteriorly directed concavity. Such concavity is the anatomical interpretation of the vertebral bodies and intervertebral discs configuration. This sagittal convexity tends to increase with age, leading to excessive curvature of the spine exceeding the normal range known as hyperkyphosis or age-related hyperkyphosis[1,2]. The expected kyphosis angle ranges from 20° to 29° kicking off from childhood throughout the third decade of an individual's life. After the fourth decade of life, the kyphotic angle begins to worsen usually more rapidly in women than men[1,3]. The kyphosis angle varies between 43° in women aged 55-60 to 52° in women aged 76-80. The clear-cut etiology of the kyphosis and its progression over time have not yet been established. Nevertheless, several studies have shed light on various risk factors such as bone mineral density, vertebral fractures, degenerative changes, reduced mobility, diminished proprioception, the spinal extensor musculature, and even heredity[4-7].

A substantial inconsistency is met in the literature regarding the relationship between kyphosis, balance, and risk of subsequent falls[8,9]. Van der Jagt-Willems et al. (2015) reported that older adults suffering from excessive kyphosis were considered prone to falling in the forthcoming year since the hyperkyphotic posture is presumed to lead to an anterior-directed movement of the individual's center of gravity causing an increased postural sway[8,10]. Furthermore, kyphotic posture is accompanied by a flexion bias around the shoulder and hip joints, which could finally lead to an alteration of the joint mechanics and movement patterns to the greatest possible extent[11]. Concerning the individual's musculature, it is perceived that a severe kyphotic change would require an increased muscle tone in favor of maintaining the posture

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compared to a less severe kyphosis. The increased muscle tone could interfere with the quick response to the surface movement changes favoring fall incidence. On the other hand, there are studies reporting no strong connection between kyphosis and impaired balance, or even highlighting the protective mechanism of kyphosis state and change in kyphosis against falls[12].

Women have a higher risk of falls than men[13]. Especially, women suffering from osteoporosis-related kyphosis face even greater balance abnormalities in regards to healthy individuals[14]. The excessive kyphosis apart from the possible fall incidence may worsen an individual's functionality such as the walking speed, the ability to rise from a chair and even the handgrip strength.

Material and methods

This is a prospective observational study aimed to evaluate the interrelationship between the annual change in kyphosis, and its direct effect on the risk of falling. 498 postmenopausal Greek women attending an outpatient osteoporosis clinic were included in the study. The inclusion criteria encompassed sex (female), age (50 to 90), postmenopausal state and diagnosis of osteoporosis or osteopenia (Osteopenia/osteoporosis was defined by BMD T-score <-1 SD at any skeletal site). Whereas, the exclusion criteria were: recent fracture in the lower extremities (≥6 months), renal or hepatic failure, neoplasms, dementia in an advanced state and use of medication that could increase the risk of falling. The study was conducted in accordance with the World Medical Association Declaration of Helsinki-Ethical Principles for Medical Research Involving Human Subjects and the ethical approval for the study was granted by the Scientific Committee of Konstantopouleio Hospital in Greece.

For each participant we collected the following: age, height, weight, and self-reported falls. Additionally, we evaluated the degree of the kyphosis angle, the balance, the mobility, the functionality and the handgrip strength on both hands using the Debrunner kyphometer, the Berg Balance Scale (BBS), the Timed-Up-and-Go (TUG) test, the 30 Seconds Sit-to-Stand (30CST) test and the Jamar Hydraulic Hand Dynamometer, respectively. All of the above documentations and evaluations were performed at the baseline visit as well as at the 12-month follow-up visit. The only exception was the self-reported falls that were documented only at the follow-up visit.

Measurements of kyphosis performed with subjects in the standing position. The one moveable arm of the kyphometer was placed on the first thoracic vertebrae (Th1) and the other arm on the last thoracic vertebrae (Th12). Furthermore, we used the Berg Balance Scale to evaluate the balance of the participants, and the Timed-Up-and-Go test, the 30 Seconds Sit-to-Stand test alongside the Jamar Hydraulic Hand Dynamometer to evaluate the functionality such as the walking pace, the ability to rise from the chair and the handgrip strength, respectively. By evaluating the degree of the kyphosis angle at the baseline visit as well as in the 12-month follow-up visit, we calculated the difference between the two distinctive results and get the annual change. In the same way, we calculated the annual change for the BBS, the 30CST, the TUG scores and the handgrip strength. Each patient's self-reported falls data were recorded at the 12-month follow-up visit. At that point we asked the subjects if they had experienced any fall from their previous visit, regardless of the cause or potential fall-related injuries. In order to avoid any misconception we defined what we considered a fall. In our study fall is defined as an unintentional change from a standing position resulting in coming to rest at a lower level.

The participants were divided into three age groups (50-69, 70-79 and 80+). Based on the degree of kyphosis in the 12-month follow-up visit, the subjects were described as hyperkyphotic or not. Currently there is no commonly accepted consensus hyperkyphosis threshold. In our study we considered the 60° of kyphosis angle as the threshold for the definition of hyperkyphosis. The measurements were performed by the same individual at the initial visit and 12-month follow-up visit.

Statistical Analysis

Data were expressed as means ± standard deviations for continuous variables and as numbers and percentages for categorical data. The normality of continuous variables was analyzed using a Kolmogorov-Smirnov test. The one-way analysis of variance model was held using the x^2 test, the Fisher's exact test, t-test. All tests were two-sided, with a p-value <0.05 denoting statistical significance. All analyses were carried out using the SPSS vr. 2100 statistical package (IBM Corporation, Somers, NY, USA).

Results

Participants had a mean age of 68.99 years (9.46 SD). The mean degree of kyphosis angle was 49.99±11.02 at baseline and 50.78±10.90 at 12-month follow-up (Table 1). Patients that showed an increase of the TUG scores after 1 year were 295 (59.23%), Also, 246 patients showed an increase in the 30CST test scores (49.39%) and only 65 patients had a better BBS score (13.05%). On the other hand, grip strength in both hands presented a decrease (0.45±0.13 vs 0.42±0.11; 0.43±0.13 vs 0.39±0.11). All variables presented a significant statistical change during the 12-month observation period (Table 1). The 30CST test variable presented a strong statistical value also in the multiple logistic regression on falls (Table 2).

The participants presented an increase of the kyphosis variable. An increase was also met in the TUG (N=295, 59.23%) and 30CST test (N=246, 49.39%). Whereas a decrease was observed on the grip strength of the right hand (N=247, 49.59%) and of the left hand (N=253, 50,80%). None of the assessed variables' annual change was associated

Table 1. Comparison of variables during the one-year observation period (kPA: kilopascal).

	Baseline Mean Value (SD)	12-month follow-up Mean Value (SD)	Mean Difference (95% CI)	p-value
Kyphosis [degrees]	49.99 (11.02)	50.78 (10.90)	0.78 (0.49/1.08)	**<0.001**
Timed Up and Go test (TUG) [sec]	8.24 (4.22)	8.77 (4.55)	0.53 (0.25/0.81)	**<0.001**
Grip strength right hand [kPA]	0.45 (0.13)	0.42 (0.11)	-0.03 (-0.04/-0.02)	**<0.001**
Grip strength left hand [kPA]	0.43 (0.13)	0.39 (0.11)	-0.04 (-0.05/-0.03)	**<0.001**
Berg Balance Scale (BBS)	55.47 (1.17)	55.58 (1.05)	0.11 (0.04/0.18)	**0.003**
30 Second Sit to Stand test (30CST)	12.52 (3.29)	13.09 (3.88)	0.57 (0.33/0.82)	**<0.001**

Table 2. Multiple logistic regression of falls. Left-hand grip strength was excluded because of collinearity (kPA: kilopascal).

	Odds Ratio	95% CI		p-value
Change in kyphosis [degrees]	0.98	0.93	1.03	0.416
Timed Up and Go test (TUG) [sec]	0.97	0.90	1.05	0.461
Grip strength right [kPA]	1.93	0.28	13.11	0.500
Berg Balance Scale (BBS)	1.18	0.90	1.54	0.229
30 Second Sit to Stand test (30CST)	0.92	0.85	1.00	**0.048**

Table 3. Unifactorial analysis of the balance variables concerning the falls.

Overall	Falls Mean (SD)		Mean Difference (95%CI)	p-value
	No	Yes		
Change in kyphosis [degrees]	0.831 (2.925)	0.587 (4.774)	-0.24 (-1.24/0.75)	0.630
Change in Timed Up and Go test (TUG) [sec]	0.583 (3.042)	0.333 (3.614)	-0.25 (-0.95/0.45)	0.482
Change in grip strength right hand [kPA]	-0.035 (0.120)	-0.025 (0.130)	0.01 (-0.02/0.04)	0.489
Change in grip strength left hand [kPA]	-0.037 (0.129)	-0.041 (0.154)	0.00 (-0.03/0.03)	0.806
Change in Berg Balance Scale (BBS)	0.080 (0.735)	0.204 (1.015)	0.12 (-0.09/0.34)	0.257
Change in 30 Second Sit to Stand test (30CST)	0.688 (2.568)	0.112 (3.549)	-0.58 (-1.33/0.18)	0.133

with falls at the 12-month follow-up for the total number of participants (Table 3), nor did they have any prognostic value for future falls (Table 4).

91 of the 248 study's participants had kyphosis angle greater than 60° (hyperkyphosis) at the 12-month follow-up visit. Specifically, hyperkyphosis were observed in 21, 36 and 34 participants in the 50-69, 70-79 and 80+ age groups, respectively. In the age group 50-69, participants with hyperkyphosis (falls: 4.8%) had 82% less possibility to experience a fall in a one-year time-period when compared with subjects without hyperkyphosis (falls: 15%) (p=0.326). In the age group 70-79, subjects with hyperkyphosis (falls: 19.4%) had 20% less possibility to experience a fall in a one-year time-period when compared subjects without hyperkyphosis (falls: 23.1%) (p=0.822). In the age group 80+, subjects with hyperkyphosis (falls: 32.4%) had 13% higher possibility to experience a fall in a one-year time-period when compared with those without hyperkyphosis (falls: 29.8%) (p=0.813). In total population, subjects with hyperkyphosis (falls: 20.9%) had 10% higher possibility to experience a fall in a one-year time-period when compared with subjects without hyperkyphosis (falls: 19.4%) (p=0.771) (Table 5).

Discussion

In our study, we examined the association between the annual change of the kyphosis in osteoporotic and osteopenic postmenopausal women, with the risk of falling. Additionally, we investigated whether or not the state of hyperkyphosis affect the fall risk. Based on our results the annual change

Table 4. ROC analysis of the annual change of the variables in regards to the falls.

Variable	AUC (95% CI)	p-value
Change in Kyphosis	0.515 (0.447-0.584)	0.640
Change in Timed Up and Go test (TUG)	0.516 (0.418-0.550)	0.622
Change in Grip strength right hand	0.539 (0.476-0.601)	0.233
Change in Grip strength left hand	0.510 (0.426-0.554)	0.762
Change in Berg Balance Scale (BBS)	0.503 (0.436-0.571)	0.919
Change in 30 Second Sit to Stand test (30CST)	0.545 (0.485-0.621)	0.165

Table 5. Correlation of hyperkyphosis at the 12-month follow-up and falls in the previous year.

Age Group	Hyperkyphosis at the 12-month follow-up		Falls in the last 12 months	
			No	Yes
50-69	No	N	192	34
		%	85.0	15.0
	Yes	N	20	1
		%	95.2	4.8
70-79	No	N	103	31
		%	76.9	23.1
	Yes	N	29	7
		%	80.6	19.4
80+	No	N	33	14
		%	70.2	29.8
	Yes	N	23	11
		%	67.6	32.4
Total	No	N	328	79
		%	80.6	19.4
	Yes	N	72	19
		%	79.1	20.9

in kyphosis was not associated with an increased risk of falling for the screened individuals nor had a prognostic value for future falls. To the best of our knowledge, this is the first published study that examined the effect of the annual change in kyphosis on the risk of falling.

Several studies demonstrated an association of increased kyphosis with incidence of falls among older adults[8,10,11]. On the other hand, other studies highlighted kyphosis's protective mechanism[12]. Thus, the effect of kyphosis on balance has not yet been fully clarified. Numerous studies, using a handful of alternative non-radiological methods of evaluating kyphosis that used poor balance as a risk factor for falling[12,15-20]. Also, women have a greater age-independent fall risk than male[13]. Women suffering from osteoporosis-related kyphosis exhibit greater balance abnormalities compared with healthy individuals[14].

What could be perceived in the course of our study is that the greater part of the assessed subjects demonstrated a slow walking pace, difficulty rising from a chair and decreased handgrip strength. All that could affect the functionality throughout the performance of activities of daily living (ADL) and fear of falling (FOF). These attributes were assessed with the TUG test, the 30CST test and the Jamar Hydraulic Hand Dynamometer. Interestingly, all these variables presented a significant statistical change at the 12-month observation period (p-value <0.001). But their annual change was not associated with falls in the 12-month for the total number of participants, nor did they have any predictive value for future falls. The only exception stood the 30CST test that in the multiple logistic regression of falls, had a correlation to falls.

A large study conducted with women subjects using also the Debrunner kyphometer highlighted that a greater degree of kyphotic angle was firmly correlated with longer TUG time[20]. Additionally, a small-range study in women concluded that individuals suffering from excessive kyphosis were expressed by a reduced gait velocity yet reduced fall efficacy compared to non-exaggerated kyphotic individuals[14]. These studies seem to support our finding in favor of the assessed subject having long TUG time, yet not increased self-reported falls. On the other hand, TUG time was not linked to falls in a study carried out by McDaniels-Davidson et al. (2018). Individuals with severe kyphotic deformities have an impaired mobility and an increased risk of falling[21]. However, TUG is a way of assessing functional performance and is not focused primarily on balance. Simultaneously fall risk in those with excessive kyphosis is mediated by other factors, such as spinal muscle weakness, etc., which are not captured by the TUG. The same is observed in the BBS, the 30CST test, and the handgrip strength evaluation. With a view to the BBS, its association with the kyphosis variable as well as the self-reported falls, two published studies showed no connection[16]. It needs to be clarified that a change of 8 points in the score would be accompanied by crucial changes in functionality[22-24] - a change that was not expected to be observed in the one-year period of our study. In a longitudinal study conducted with 100 healthy men and women (≥50 years old), a mean increase in the thoracic kyphotic angle of 3° per decade was reported[25]. Additionally, in a 15-year retrospective cohort study of older women, the kyphosis angle showed a progression of 2.6° between the baseline and 3-year follow-up yet an even greater 7.1° between the baseline and 15-year follow-up evaluation[26].

Limitations

Our study has some limitations worth noting. One limitation is the short follow-up period. Each participant was assessed twice (at the baseline visit and at the 12-month follow-up).

Moreover, in our study we used a non-radiological method to evaluate the kyphosis, which could have an influence on measurement results. Lastly, we should not ignore the fact that older adults modestly underreport their falls.

Conclusions

To conclude, based on our results the annual change of kyphosis in postmenopausal osteopenic and osteoporotic women was not associated with the risk of falling. Additionally, no large-scale changes were met regarding participants' functionality, mobility, and balance. Further studies are necessary in order to confirm our findings.

References

1. Fon GT, Pitt MJ, Thies AC Jr. Thoracic kyphosis: range in normal subjects. AJR Am J Roentgenol 1980; 134:979-983.
2. Voutsinas SA, MacEwen GD. Sagittal profiles of the spine. Clin Orthop Relat Res 1986;210:235-42.
3. Ensrud KE, Black DM, Harris F, Ettinger B, Cummings SR. Correlates of kyphosis in older women. The Fracture Intervention Trial Research Group. J Am Geriatr Soc 1997;45:682-687.
4. Milne JS, Lauder IJ. The relationship of kyphosis to the shape of vertebral bodies. Ann Hum Biol 1976;3:173-179.
5. Anderson DE, D'Agostino JM, Bruno AG, et al. Variations of CT-based trunk muscle attenuation by age, sex, and specific muscle. J Gerontol A Biol Sci Med Sci 2013; 68:317-323.
6. Kamel HK. Sarcopenia and aging. Nutr Rev 2003; 61:157-167.
7. Van der Klift M, De Laet CE, McCloskey EV, et al. The incidence of vertebral fractures in men and women: the Rotterdam Study J Bone Miner Res 2002;17:1051-1056.
8. Lynn SG, Sinaki M, Westerlind KC. Balance characteristics of persons with osteoporosis. Arch Phys Med Rehabil 1997;78:273-277.
9. Ishikawa Y, Miyakoshi N, Kasukawa Y, et al. Spinal curvature and postural balance in patients with osteoporosis. Osteoporos Int 2009;20:2049-2053.
10. Van der Jagt-Willems HC, de Groot MH, van Campen JP, et al. Associations between vertebral fractures, increased thoracic kyphosis, a flexed posture and falls in older adults: a prospective cohort study. BMC Geriatr 2015;15:34.
11. Katzman WB, Wanek L, Shepherd JA, Sellmeyer DE. Age-related hyperkyphosis: its causes, consequences, and management. J Orthop Sports Phys Ther 2010; 40:352-360.
12. Choi CJ, Lim HW, Park MK, Cho JG, Im GJ, Chae SW. Does the kyphotic change decrease the risk of fall? Clin Exp Otorhinolaryngol 2011;4(3):118-21.
13. Kado DM, Miller-Martinez D, Lui LY, Cawthon P, Katzman WB, Hillier TA, Fink HA, Ensrud KE. Hyperkyphosis, kyphosis progression, and risk of non-spine fractures in older community dwelling women: the study of osteoporotic fractures (SOF). J Bone Miner Res 2014; 29(10):2210-6.
14. Sinaki M, Brey RH, Hughes CA, Larson DR, Kaufman KR. Balance disorder and increased risk of falls in osteoporosis and kyphosis: significance of kyphotic posture and muscle strength. Osteoporos Int 2005; 16:1004-1010.
15. de Groot MH, van der Jagt-Willems HC, van Campen JP, Lems WF, Beijnen JH, Lamoth CJ. A flexed posture in elderly patients is associated with impairments in postural control during walking. Gait Posture 2014; 39:767-772.
16. Eum R, Leveille SG, Kiely DK, Kiel DP, Samelson EJ, Bean JF. Is kyphosis related to mobility, balance, and disability? Am J Phys Med Rehab 2013;92:980-989.
17. Antonelli-Incalzi R, Pedone C, Cesari M, Di Iorio A, Bandinelli S, Ferrucci L. Relationship between the occiput-wall distance and physical performance in the elderly: a cross sectional study. Aging Clin Exp Res 2007;19:207-212.
18. Balzini L, Vannucchi L, Benvenuti F et al. Clinical characteristics of flexed posture in elderly women. J Am Geriatr Soc 2003;51:1419-1426.
19. Greig AM, Bennell KL, Briggs AM, Wark JD, Hodges PW. Balance impairment is related to vertebral fracture rather than thoracic kyphosis in individuals with osteoporosis. Osteoporos Int 2007;18:543-551.
20. Katzman WB, Vittinghoff E, Ensrud K, Black DM, Kado DM. Increasing kyphosis predicts worsening mobility in older community-dwelling women: a prospective cohort study. J Am Geriatr Soc 2011;59:96-100.
21. McDaniels-Davidson C, Davis A, Wing D, Macera C, Lindsay SP, Schousboe JT, Nichols JF, Kado DM. Kyphosis and incident falls among community-dwelling older adults. Osteoporos Int 2018;29(1):163-169.
22. Berg K et al. The Balance Scale: Reliability Assessment with elderly residents and patients with an acute stroke. Scand J Rehabil Med 1995;27(1):27-36.
23. Usuda S, Araya K, Umehara K, Endo M, Shimizu T, Endo F. Construct validity of functional balance scale in stroke inpatient. J Phys Ther Sci 25:1043-1049.
24. Whitney S, D. Wrisley et al. Concurrent validity of the Berg Balance Scale and the Dynamic Gait Index in people with vestibular dysfunction. Physiother Res Int 2003;8(4):178-86.
25. Kobayashi T, Atsuta Y, Matsuno T, et al. A longitudinal study of congruent sagittal spinal alignment in an adult cohort. Spine 2004;29:671-676.
26. Kado DM, Huang MH, Karlamangla AS, et al. Factors associated with kyphosis progression in older women: 15 years' experience in the study of osteoporotic fractures. J Bone Miner Res 2013;28:179-187.