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REVIEW ARTICLE

Methods of Postural Assessment used in Hyperkyphotic Elders: A Narrative Review

Sunil Kumar, Deepika Singla, and Manju Chhugani

Jamia Hamdard

*dpkasingla@gmail.com

ABSTRACT

Background and objective: Aging is a natural process and associated changes in posture, mainly at the spine lead to complications in functional independence and quality of life. The aim of this review is to identify existing measuring tools used to measure hyperkyphotic posture in the elderly population.

Methods: Electronic databases were searched from January 2001 to December 2021, with different combinations of keywords, "thoracic kyphosis" or "hyperkyphosis" or "kyphotic posture" or hyperkyphotic posture" or "flexed posture" or "spinal curve" and "assessment", "measurement" or "instrument" or "equipment" and "elderly" or "older adults" or "elders". Studies were selected based on inclusion and exclusion criteria.

Results: Four thousand one hundred sixty-six studies were obtained from electronic databases. After the removal of 3227 duplicate studies, twenty-six relevant studies were selected from 939 unique studies. Radiographic measurement, Flexicurve ruler, Debrunner kyphometer, Gravity-dependent inclinometer, occiput to wall distance (OTW), tragus to wall distance (TWD), and spinal mouse were used for hyperkyphotic measurement. The radiographic method and Flexicurve showed very high reliability. The block method and flexicurve are widely used methods for assessing hyperkyphotic posture in older adults.

Conclusion: Postural assessment methods showed variability in defining criteria for hyperkyphosis in the elderly population. Flexicurve and block methods can be used as non-invasive methods for the early detection of hyperkyphosis. In the future, more measurement tools should be developed for the measurement of kyphosis, that are cost-effective, with excellent reliability and validity.

Keywords: Kyphosis; Posture; Aged; Thorax; Spine.

Introduction

Postural changes are a very common phenomenon with advanced age.[1,2] Changes in the thoracic spine with advanced age contribute to hyperkyphosis, the exaggeration of the anterior curvature of the thoracic spine is known as hyperkyphosis. The prevalence of hyperkyphosis is 20 to 40 percent in the elderly population.[3,4] Increasing thoracic kyphosis leads to limit spinal mobility, reduces pulmonary functions, affects balance, decreases physical performance, and affects the quality of life.[3,5] Hyperkyphosis is associated with morbidity and mortality in older elders.[3,6,7] Quantitative measurement is essential for the evaluation of hyperkyphosis. So early detection can limit the advancement of hyperkyphosis posture in older adults.

Although in past years different postural assessment tools were developed for kyphosis assessment like radiographic method, flexicurve, debrunner kyphometer, gravity-dependent inclinometer, tragus to wall distance, block method, occiput-to-wall (OTW), photographic method, and spinal mouse, yet there was no clear agreement on assessment method, suited best for determining hyperkyphotic posture.[3] The radiological method is considered the gold standard for determining the cobb's angle, but its radiation effects, discourage the use of the radiographic method.[8] There were no clear defining criteria for hyperkyphosis.[5,9] The objective of this review is to provide a comprehensive overview of methods and equipment used to determine hyperkyphosis in the elderly population.

Methods

The PubMed, Cochrane Library, Google Scholar, Research Gate, Scopus, and Education Resources Information Center (ERIC), databases were searched with the combination of the following keywords was used: "kyphosis" OR "hyperkyphosis" OR "spine", OR "posture", OR "flexed posture", AND "assessment", OR "measurement", AND "elders", OR "older adults", OR "elderly".

Inclusion criteria were as follows: (1) The studies must have older adults aged ≥ 60 years; (2) studies must be published in the English language; (3) studies must include hyperkyphotic subjects. Exclusion criteria were as follows: (1) studies were not included if no measurement tool was used for the measurement of hyperkyphosis; (2) studies were excluded if hyperkyphosis is congenital or not age-related hyperkyphosis; (3) the systematic review, case reports, and narrative reviews were also excluded. This literature review examines the methods used in the last two decades for kyphotic posture assessment in older adults aged ≥ 60 years.

After removing duplicate studies, two independent reviewers performed a screening of titles and abstracts. Full-text studies were reviewed based on the inclusion criteria. Relevant studies were selected for this review. The disagreements were resolved by discussion. The identification and selection of studies are summarized in Figure 1.

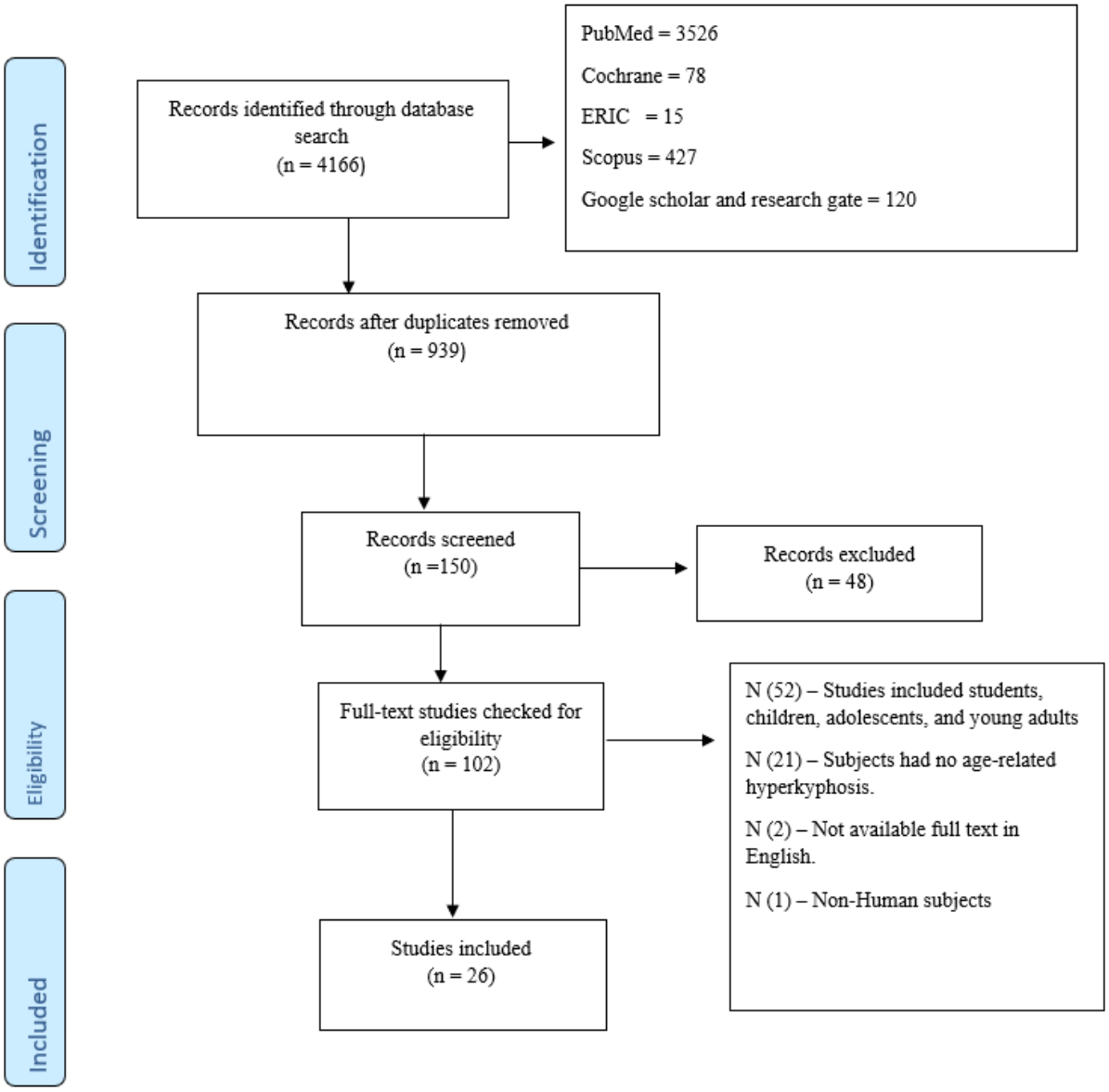

Figure 1: Flow chart for studies selection

Results and Discussion

The electronic database search produced 4166 studies. One hundred fifty relevant studies were identified through reading titles and abstracts. Twenty-six studies were selected after complying with inclusion criteria and exclusion criteria. The characteristics of selected studies are summarized in Table 1.

Of all 26 studies included in this review, The age of the participants varied from 60 years to 88 years. The angle of thoracic kyphosis ranged from 40° to 50° as a cut-off angle for defining hyperkyphosis. Lateral radiographic, Flexicurve ruler, Debrunner kyphometer, Gravity-dependent inclinometer, Tragus to wall distance (TWD), Occiput-wall distance (OWD), Block Method, and Spinal Mouse device are the methods used in the selected studies for the measurement of posture. The reliability and validity of methods used for kyphosis assessment are described in Table 2.

Table 1: Summary of selected studies

S.no.	Author(s) name	Year	Main inclusion criteria	Sample size	Mean Age (yr) ± SD	Measurement Tool/s	Method/s used to measure hyperkyphotic posture
1.	Karimian, M. R., et al.[10]	2021	Age > 60 yrs., thoracic kyphosis ≥45°	15	62 ± 2	Manual kyphometer (Ghamatpoyan Co, Iran)	Kyphometer placed at 7th cervical (C7) and 12th thoracic (T12) spinous process, 3 measurements taken to reduce error.
2.	Kaufmann et al.[11]	2020	Age > 65yr	754	79.5 ± 5.3	Rancho Bernardo block method	1.7 cm block was used to measure the distance between the participant's occiput and table.
3.	Roghani, T., et al.[12]	2019	Age > 60yr, thoracic kyphosis ≥50°	24	65 ± 4.4	Spinal Mouse	Spinal mouse rolled over dorsal spine to determine hyperkyphosis.
4.	Katzman, W. B. et al.[13]	2019	Age ≥65 yrs., thoracic kyphosis ≥40°	64	71.6 ± 4.9	Debrunner kyphometer	Interspace between T2/T3 and T11/T12 used as a landmark for measurement.
5.	Jang, H. J., et al.[14]	2019	Age > 65yr, thoracic kyphosis ≥40°	50	74 ± 4.6	1. Dual inclinometer (F00550, Acumar, Lafayette Instrument Company 2. Flexicurve 3. Targus to wall distance (TWD)	1. Inclinometer placed between T1 and L1 spinous process. 2. 60 cm ruler placed on the surface of thoracic curvature. 3. 30-cm ruler used to measure the distance between wall and Tagus, while participant standing in relax position
6.	Watson, S. L et al.[15]	2019	Age > 60yr,	51	64 ± 4.5	1. Dual-energy X-ray absorptiometry (DXA) 2. Inclinometer 3. Flexicurve	1. Cobb's angle was determined by software using lateral vertebral scan. 2. Inclinometer ends placed on C7and T12 for measurement. 3. Flexicurve molded from C7 to T12.
7.	Sugai, K., et al.[16]	2019	Age ≥65 yrs	403	-	Block method	1.5 cm block used between participant's head and table.
8.	Naderi, A., et al.[17]	2019	Age > 65yr, thoracic kyphosis ≥50°	24	68.7 ± 2.6	Flexicurve	Flexicurve placed at T2 and T12 spinous process.
9.	McDaniels-Davidson et al.[18]	2018	Age > 60yr thoracic kyphosis angle (TKA) ≥40°	72	77.8 ± 7.1	1. DXA based lateral vertebral scan 2. Flexicurve ruler 3. Block Method	1. DXA scan was used to calculate the cobb's angle. 2. Flexicurve aligned with the back. 3. 1.7 cm blocks were used to make the head in a neutral position.
10.	Katzman, W. B., et al.[19]	2017	Age ≥60 yrs., thoracic kyphosis ≥40°	99	70.6 ± 0.6	1. Lateral spine radiograph 2. Debrunner kyphometer (Techmedica Inc., Camarillo, CA)	1. The superior endplate of T4 and the inferior endplate of T12 vertebra were used to determine Cobb's angle. 2. Interspace between T2/3 and T11/12 used as a landmark for measurement through a kyphometer.
11.	Katzman, W. B., et al.[20]	2017	Age > 60 yrs., thoracic kyphosis ≥40°	101	70.0 ± 5.7	1. Lateral spinal radiograph, 2. Kyphometer	1. Cobb's angle measured with standardized protocol. 2. Kyphometer placed externally over T2/T3 and T11/T12 interspace.
12.	Roghani et al.[21]	2017	Age > 60yr, thoracic kyphosis angle ≥50°	19	67 ± 5	Spinal mouse	Spinal mouse rolled over the back for measurement.
13.	Yokoyama, Y., et al.[22]	2017	Age > 65yr,	792		Block method	1.5 cm block was used, to measure the distance between the participant's occiput and table.

14.	Yamamoto, J., et al.[23]	2017	Age > 65yr,	72	77.8 ± 7.1	1. DXA Scan, 2. Debrunner kyphometer, 3. Flexicurve ruler, 4. Blocks method	1. The superior aspect of T4 and the inferior surface of T12 was used to determine the cobb's angle. 2. The T2 and T12 were marked for measurement for the debrunner kyphometer. 3. Flexicurve was molded to the spinal curve from C7 to L5. 4. 1.7 cm thick block was used to measure the distance between the participant's head and table, in a supine position.
15.	Tran et al.[24]	2016	Age > 65yr,	72	76.9 ± 6.7	1. DXA based, lateral vertebral scan 2. Debrunner kyphometer 3. Flexicurve ruler 4. Blocks method	1. DXA, cobb's angle determined by the standard method, 2. Debrunner kyphometer placed between interspace of T2-T3 and interspace between T11-T12. 3. Flexicurve ruler molded from 7th cervical vertebra to interspace between L5 and S1. 4. 1.7 cm thick block used in between participant's head and plinth.
16.	Jang, H. J., et al.[25]	2015	Age > 65yr, thoracic kyphosis angle ≥45°	41	73.8	Gravity-dependent inclinometers (Isomed Inc., Portland, OR, USA)	Two inclinometers were used, first placed at spinous processes of T1 and T2, and the other at T12 and L1, vertebra.
17.	Katzman, W. B., et al.[26]	2015	Age > 65yr,	2363	79 ± 5	Block method	1.7-cm block was placed between the participant's head and table.
18.	Van der Jagt-Willems, H. et al.[27]	2015	Age > 70yr,	51	79 ± 4.8	1. Lateral X-rays 2. Occiput-to-wall distance (OWD)	1. The superior surface of the T12 vertebra and the inferior surface of T12 was used to determine the cobb's angle. 2. Distance between the occiput and the wall measured in the neutral position.
19.	Hojjati, Z., & Sheikhpour, L. [28]	2013	Age > 60yr, thoracic kyphosis angle (TKA) ≥40°	23	67.1 ± 4.1	Flexicurve	Flexible ruler molded over the contour of the spine from C7 to T12 vertebra.
20.	Quek, J., et al.[29]	2013	Age > 60yr,	51	66 ± 4.9	Flexicurve	Flexicurve placed over the dorsal spine from C7 to S2, in usual posture.
21.	Azadinia, F et al. [30]	2013	Age > 60yr, thoracic kyphosis angle (THA) ≥50°	20	66.7 ± 4.7	Lateral spinal radiographs	The standardized protocol was followed for cobb's angle measurement.
22.	Katzman, W., et al.[31]	2012	Age > 70 yrs.	1172	73.6 ± 2.8	Lateral CT scans	The standard measure used for kyphosis.
23.	Bautmans, I., et al.[32]	2010	Age ≥ 69 yrs.	48	76 ± 7	Spinal Mouse (Idiag, Fehraltorf, Switzerland).	The wireless spinal mouse rolled from C7 to S3.
24.	Regolin, F., & Carvalho, G. A.[33]	2010	Age > 60yr,	95	67.2 ± 5.01	Flexicurve method	Flexicurve used to determine kyphotic posture.
25.	Greendale et al.[34]	2009	Age > 60yr, thoracic kyphosis angle (TKA) ≥40°	118	75.5	1. Debrunner kyphometer 2. Flexicurve 3. Rancho Bernardo Blocks (RBS-Blocks)	1. C7 and T12 vertebra used as bony landmarks. 2. flexicurve molded on dorsal spine. 3. Rancho Bernardo Block was used to measure forward head posture.

26.	Hinman, M. R. [35]	2004	Age > 66 yrs.	26	72.3	Flexicurve (Alvin, Hartford, CT)	Flexicurve placed over dorsal spine from C7 to S1.

Table 2: Reliability and validity of methods used for the assessment of thoracic kyphosis.

Method	Reliability	Validity
Radiography X-ray (Lateral radiograph measure cobb's angle)	Excellent test-retest reliability Intraclass correlation coefficients: ICC = 0.90.[19]	Excellent validity
Flexicurve ruler	1. The inter-rater reliability (ICC) ranged from 0.73 to 0.93 2. Intrarater reliability raged from 0.86 to 0.90.[34]	Moderate to high Validity: ICC = 0.96
Debrunner kyphometer	1. Interrater reliability from 0.89 to 0.96 2. Intrarater reliability ranged from 0.93 to 0.98.[34]	Moderate validity: ICC ranged from 0.62 to 0.76.[4]
Gravity-dependent inclinometer	1. Excellent intrarater reliability (ICC = 0.96 (95% CI, 0.95–0.97).[15] 2. Interrater reliability: ICC ranged from 0.89 to 0.94.[13]	High validity: ICC = 0.81
Occiput-wall distance (OWD)	The intrarater reliability: ICC= 0.99 and interrater reliability: ICC= 0.93.[13]	-
Spinal Mouse device	Intra-observer reliability: ICC = 0.73-0.88.[34] Inter observer reliability: ICC = 0.83-0.87.[34]	Moderate to high validity: ICC ranged from 0.76 to 0.98.

Lateral spine radiographic

The Lateral spine radiographic method is considered a gold standard tool for the measurement of kyphosis.[8] For taking an X-ray for kyphosis, one must stand straight barefoot, both knees straight, and take full inspiration during the lateral scan. Two lines are drawn, first from the superior endplate of the 4th thoracic vertebrae and the second one from the inferior endplate of the 12th thoracic vertebrae, and the angle formed in between the two perpendiculars on these lines is considered as cobb's angle.[19] The greater the angle of kyphosis, the more the severity of kyphosis. This method has high interrater and intrarater reliability reported so far, although the limitation of the radiographic method is radiation exposure.[5]

Flexicurve ruler

Flexicurve is one of the simplest non-invasive method used for the assessment of posture in elders.[36] A flexicurve ruler is 50 cm in length and 2 cm wide and it is used to determine the kyphosis index. For the measurement, two anatomical landmarks are marked on the dorsal spine, and then a semi-flexible ruler takes the shape of the curvature of the spine after the curve is recreated on paper to determine the angle of the thoracic kyphosis. For measurement one stands still in a comfortable position, legs should be apart, and then flexicurve placed on the exposed anatomical landmarks of the spine. The 7th cervical vertebra (C7) to the 12th thoracic vertebra (T12) are used as anatomical landmarks. Greendale et al. reported that the flexicurve is more accurate and more precise than the Debrunner instrument.[34]

Debrunner kyphometer

Debrunner kyphometer is a non-invasive, protractor-like mechanical device that is used to measure kyphosis.[39,40] It is mounted at both ends and the angle of kyphosis is determined through the angle made by the protractor. This device has a one-degree precision.[34] Debrunner kyphometer placed between the interspace of 2nd and 3rd thoracic spinous process and another anatomical landmark used as interspace between 11th and 12th thoracic spinous process.[19] For the measurement, one needs to stand straight, in a relaxed posture. The angle recorded from the

protractor is named as kyphosis angle with debrunner kyphometer.

Gravity-dependent inclinometer

Gravity-dependent inclinometers are used to measure kyphosis. Dual inclinometer consists of 2 inclinometers with 2 feet on the bottom face, used to measure of Angle of Thoracic Kyphosis (ATK).[25] The measurement from the inclinometer can be taken in a relaxed standing posture or standing tall.[15] One needs to stand straight as tall as possible for measurements. Inclinometer placed over the spinal processes of T1 and T2, and the T12 and L1 vertebrae. The thoracic kyphosis angle can be measured and recorded by checking the angles displayed on the inclinometers.

Tragus to wall distance (TWD)

Tragus to wall distance is used to measure Forward Head Posture (FHP), a conventional, quick, and cost-effective measurement tool. This method required a ruler of 30 cm in length and a wooden block of a width of 5 cm, the participant need to stand still and a wooden block has to place between the participant's heel and wall to avoid trunk movement. The distance between the wall and tragus is noted with help of the ruler. Three trials are allowed and the average of three is considered for final scoring.[14]

Occiput-wall distance (OWD)

The occiput to wall distance method is a cheap, easy, and quick alternative method for the assessment of kyphosis. This method of assessment required only two rulers must be placed perpendicular, one vertically touching the occiput and another one placed horizontally from wall to occiput. The horizontal scale provides a reading of the distance from the wall to the occiput. For measurement one should stand stood with heels together, pelvis touching the wall and head positioned in Frankfort horizontal plane. If the score is more than 5 cm, then it reflects the risk of hyperkyphosis. The advantage of this method is very easy to perform as compared to other methods of kyphosis measurement. Can be used for screening purposes to determine the severity of kyphosis in older adults.[13]

Block Method

This is another method used for the assessment of kyphosis, in this method a block of 1.5 cm height is used. The subject has to lie on their back on a table and the examiner put the blocks in between the table and the occiput.[26] The number of blocks used will determine the severity of kyphosis. The more the blocks are used more the severe kyphosis. If 0-2 blocks are used then it is classified as mild kyphosis and if 3 blocks are used then it is classified as severe kyphosis.[16] The block method is an effective and practical tool for screening and assessing hyperkyphosis in the elderly.[41]

Spinal Mouse device

It is an electronic device comprising a hand-held inclinometer that is connected to a computer wirelessly. Participants sit upright and then maximally flexed position on an armless chair. Examiner rolls the spinal mouse paravertebrally along the spine from the 7th cervical vertebra to the 3rd sacral vertebra. Each measurement was repeated thrice and the mean score from the measurement was considered the final score. This device does not require any induvial to calculate the angle of thoracic, measurement can be done with the help of the software. This device can be used for screening for hyperkyphotic posture. Another advantage of this device is that it can be used for mobility assessment of the spine.[21]

This study is the first of its kind of study that gives a detailed description of the various method used for the assessment of kyphosis in the elderly population. The most frequent method used to screen kyphotic posture is the block method, since it requires minimal skills to perform, is inexpensive in nature, and is also convenient for the participants. The radiography method is used more commonly for defining hyperkyphosis via cobb's angle. The radiography method showed excellent interrater and intrarater reliability and validity. The major disadvantage of this method is its cost and harmful radiation effects. It's practically not possible to screen a large sample with the radiography method. Flexicurve is one the cheapest non-invasive method for assessing kyphosis, the major advantage of using flexicurve is its excellent reliability and validity when compared to the radiography method. The disadvantage of this method is participant's body type affects the measurement values.

Debrunner kyphometer and inclinometer are used for determining the angle of thoracic kyphosis, both instruments showed high reliability.[4] The kyphometer sometimes wobbles on the thoracic spine at T7th or T12th, this instability needs to be corrected for precise measurement. The variability of placement of instruments on the dorsal spine was noted in this review. Occiput-wall distance (OWD) and 7th cervical vertebra wall distance (C7WD) are also used for the assessment of kyphotic posture, these methods are cheap and quick for screening the kyphotic posture. No study was found in this review that used photographic methods for determining hyperkyphotic posture in the elderly population. Spinal mouse and photographic methods are the

advanced methods for the analysis of hyperkyphotic posture few studies used the spinal mouse to quantify kyphosis. Spinal mouse showed high reliability and validity. The spinal mouse was found to be not a widely used measurement method, future studies need to be conducted to find the correlation between the spinal mouse and other measures of kyphosis.

Conclusion

This review showed the variability in defining criteria for hyperkyphosis in the elderly population. Lack of uniformity found in choosing anatomical landmarks for the measurement of hyperkyphotic posture. The block method and flexicurve are widely used methods for assessing hyperkyphotic posture in older adults. This review suggested that more measurement tools should be developed for the measurement of hyperkyphosis, that are more consistence, cost-effective, quick, easy to use, and with excellent reliability and validity.

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References

1. Benedetti MG, Berti L, Presti C, Frizziero A, Giannini S. Effects of an adapted physical activity program in a group of elderly subjects with flexed posture: clinical and instrumental assessment. J Neuroeng Rehabil. 2008;5:32. Published 2008 Nov 25. doi:10.1186/1743-0003-5-32
2. Ailon T, Shaffrey CI, Lenke LG, et al., Progressive spinal kyphosis in the aging population. *Neurosurgery*. 2015;*77* Suppl 4:S164-S172. doi:10.1227/NEU.0000000000000944
3. Bansal S, Katzman WB, Giangregorio LM. Exercise for improving age-related hyperkyphotic posture: a systematic review. *Arch Phys Med Rehabil*. 2014;*95*(1):129-140. doi:10.1016/j.apmr.2013.06.022
4. Roghani T, Zavieh MK, Manshadi FD, et al., Age-related hyperkyphosis: update of its potential causes and clinical impacts—narrative review. *Aging clinical and experimental research*. 2017 Aug;*29*(4):567-77. https://doi.org/10.1007/s40520-016-0617-3
5. Koelé MC, Lems WF, Willems HC. The Clinical Relevance of Hyperkyphosis: A Narrative Review. *Front Endocrinol (Lausanne)*. 2020;*11*:5. Published 2020 Jan 24. doi:10.3389/fendo.2020.00005
6. Kado DM, Miller-Martinez D, Lui LY, et al. 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):2210-2216. doi:10.1002/jbmr.2251
7. Wang MY, Greendale GA, Kazadi L, Salem GJ. Yoga improves upper-extremity function and scapular posturing in persons with hyperkyphosis. *Journal of yoga & physical therapy*. 2012 Jun 6;*2*(3):117. doi:10.4172/2157-7595.1000117
8. Katzman WB, Wanek L, Shepherd JA, et al., Age-related hyperkyphosis: its causes, consequences, and management. *J Orthop Sports Phys Ther*. 2010;*40*(6):352-360. doi:10.2519/jospt.2010.3099
9. Roghani T, Zavieh MK, Talebian S, Baghban AA, Katzman W. Back muscle function in older women with age-related hyperkyphosis: A comparative study. *Journal of Manipulative and Physiological Therapeutics*. 2019 May 1;*42*(4):284-94. doi:10.1016/j.jmpt.2018.11.012
10. Karimian MR, Yeowell G, Saberi S, et al. A comparison of the effectiveness of three types of trunk orthoses on the balance performance of older people with osteoporotic hyperkyphosis: A cross-over study. *Musculoskelet Sci Pract*. 2021;*55*:102430. doi:10.1016/j.msksp.2021.102430
11. Kaufmann CN, Shen J, Woods GN, et al. Hyperkyphosis and self-reported and objectively measured sleep quality in older men. *PLoS One*. 2020;*15*(2):e0228638. Published 2020 Feb 11. doi:10.1371/journal.pone.0228638
12. Roghani T, Khalkhali Zavieh M, Rahimi A, et al. The Reliability of Standing Sagittal Measurements of Spinal Curvature and Range of Motion in Older Women With and Without Hyperkyphosis Using a Skin-Surface Device. *J Manipulative Physiol Ther*. 2017;*40*(9):685-691. doi:10.1016/j.jmpt.2017.07.008
13. Katzman WB, Gladin A, Lane NE, et al. Feasibility and Acceptability of Technology-Based Exercise and Posture Training in Older Adults With Age-Related Hyperkyphosis: Pre-Post Study. *JMIR Aging*. 2019;*2*(1):e12199. doi:10.2196/12199
14. Jang HJ, Hughes LC, Oh DW, Kim SY. Effects of Corrective Exercise for Thoracic Hyperkyphosis on Posture, Balance, and Well-Being in Older Women: A Double-Blind, Group-Matched Design. *J Geriatr Phys Ther*. 2019;*42*(3):E17-E27. doi:10.1519/JPT.0000000000000146
15. Watson SL, Weeks BK, Weis LJ, et al. High-intensity exercise did not cause vertebral fractures and improves thoracic kyphosis in postmenopausal women with low to very low bone mass: the LIFTMOR trial. Osteoporos Int. 2019;30(5):957-964. doi:10.1007/s00198-018-04829-z
16. Sugai K, Michikawa T, Takebayashi T, et al. Association between muscle strength, mobility, and the progression of hyperkyphosis in the elderly: The Kurabuchi Cohort Study. *J Gerontol A Biol Sci Med Sci*. 2019;*74*(12):1987-1992. doi:10.1093/gerona/glz136
17. Naderi A, Rezvani MH, Shaabani F, et al. Effect of kyphosis exercises on physical function, postural control and quality of life in elderly men with hyperkyphosis. *Iranian Journal of Ageing*. 2019 Jan 10;*13*(4):464-79.

18. McDaniels-Davidson C, Davis A, Wing D, et al. Kyphosis and incident falls among community-dwelling older adults. *Osteoporos Int*. 2018;*29*(1):163-169. doi:10.1007/s00198-017-4253-3
19. Katzman WB, Parimi N, Gladin A, et al. Sex differences in response to targeted kyphosis specific exercise and posture training in community-dwelling older adults: a randomized controlled trial. *BMC Musculoskelet Disord*. 2017;*18*(1):509. Published 2017 Dec 4. doi:10.1186/s12891-017-1862-0
20. Katzman WB, Vittinghoff E, Lin F, et al. Targeted spine strengthening exercise and posture training program to reduce hyperkyphosis in older adults: results from the study of hyperkyphosis, exercise, and function (SHEAF) randomized controlled trial. *Osteoporos Int*. 2017;*28*(10):2831-2841. doi:10.1007/s00198-017-4109-x
21. Roghani T, Khalkhali Zavieh M, Talebian S, et al. Back muscle function in older women with age-related hyperkyphosis: A Comparative Study. J *Manipulative Physiol Ther*. 2019;*42*(4):284-294. doi:10.1016/j.jmpt.2018.11.012
22. Yokoyama Y, Nishiwaki Y, Michikawa T, et al. The association of kyphosis assessed in supine and standing positions with future activities of daily living dependence: the Kurabuchi Study. *Arch Osteoporos*. 2017;*12*(1):105. Published 2017 Nov 22. doi:10.1007/s11657-017-0401-9
23. Yamamoto J, Bergstrom J, Davis A, et al. Trunk lean mass and its association with 4 different measures of thoracic kyphosis in older community dwelling persons. *PLoS One*. 2017;*12*(4):e0174710. Published 2017 Apr 3. doi:10.1371/journal.pone.0174710
24. Tran TH, Wing D, Davis A, et al. Correlations among four measures of thoracic kyphosis in older adults. *Osteoporos Int*. 2016;*27*(3):1255-1259. doi:10.1007/s00198-015-3368-7
25. Jang HJ, Kim MJ, Kim SY. Effect of thorax correction exercises on flexed posture and chest function in older women with age-related hyperkyphosis. *J Phys Ther Sci*. 2015;*27*(4):1161-1164. doi:10.1589/jpts.27.1161
26. Katzman WB, Harrison SL, Fink HA, et al. Physical function in older men with hyperkyphosis. *J Gerontol A Biol Sci Med Sci*. 2015;*70*(5):635-640. doi:10.1093/gerona/glu213
27. van der Jagt-Willems, Hanna C et al. "Associations between vertebral fractures, increased thoracic kyphosis, a flexed posture and falls in older adults: a prospective cohort study." *BMC geriatrics* vol. 15 34. 28 Mar. 2015, doi:10.1186/s12877-015-0018-z
28. Hojjati Zidashti, Zahra & Sheikhpour, Leila. (2013). Seated exercise therapy improves posture and balance in hyperkyphotic elderly females, a Randomized Control Trail. *World Applied Sciences Journal. 24*. 331-335, doi: 10.5829/idosi.wasj.2013.24.03.794
29. Quek J, Pua YH, Clark RA, et al. Effects of thoracic kyphosis and forward head posture on cervical range of motion in older adults. *Man Ther*. 2013;*18*(1):65-71. doi:10.1016/j.math.2012.07.005
30. Azadinia F, Kamyab M, Behtash H, et al. The effects of two spinal orthoses on balance in elderly people with thoracic kyphosis. *Prosthet Orthot Int*. 2013;*37*(5):404-410. doi:10.1177/0309364612474487
31. Katzman W, Cawthon P, Hicks GE, et al. Association of spinal muscle composition and prevalence of hyperkyphosis in healthy community-dwelling older men and women. *J Gerontol A Biol Sci Med Sci*. 2012;*67*(2):191-195. doi:10.1093/gerona/glr160
32. Bautmans I, Van Arken J, Van Mackelenberg M, et al. Rehabilitation using manual mobilization for thoracic kyphosis in elderly postmenopausal patients with osteoporosis. *J Rehabil Med*. 2010;*42*(2):129-135. doi:10.2340/16501977-0486
33. Regolin F, Carvalho GA. Relationship between thoracic kyphosis, bone mineral density, and postural control in elderly women. *Brazilian Journal of Physical Therapy*. 2010;*14*:464-9.
34. Greendale GA, Huang MH, Karlamangla AS, et al. Yoga decreases kyphosis in senior women and men with adult-onset hyperkyphosis: results of a randomized controlled trial. *J Am Geriatr Soc*. 2009;*57*(9):1569-1579. doi:10.1111/j.1532-5415.2009.02391.x
35. Hinman MR. Comparison of thoracic kyphosis and postural stiffness in younger and older women. *Spine J*. 2004;*4*(4):413-417. doi:10.1016/j.spinee.2004.01.002
36. Kado DM, Lui LY, Ensrud KE, et al. Hyperkyphosis predicts mortality

independent of vertebral osteoporosis in older women. *Ann Intern Med*. 2009;*150*(10):681-687. doi:10.7326/0003-4819-150-10-200905190-00005

37. Ebrahim Mousavi M, Ahmadi Bani M, Aboutorabi A, et al. The effect of a semi-rigid thoracolumbosacral orthosis (TLSO) on foot pressure in elderly subjects presenting with spinal hyperkyphosis. *Disabil Rehabil Assist Technol*. 2020;*15*(2):205-210. doi:10.1080/17483107.2018.1555289
38. Mohebi S, Torkaman G, Bahrami F, et al. Postural instability and position of the center of pressure into the base of support in postmenopausal osteoporotic and nonosteoporotic women with and without hyperkyphosis. *Arch Osteoporos*. 2019;*14*(1):58. Published 2019 Jun 3. doi:10.1007/s11657-019-0581-6
39. Kado DM, Prenovost K, Crandall C. Narrative review: hyperkyphosis in older persons. *Ann Intern Med*. 2007;*147*(5):330-338. doi:10.7326/0003-4819-147-5-200709040-00008
40. González-Gálvez N, Gea-García GM, Marcos-Pardo PJ. Effects of exercise programs on kyphosis and lordosis angle: A systematic review and meta-analysis. *PLoS One*. 2019;*14*(4):e0216180. Published 2019 Apr 29. doi:10.1371/journal.pone.0216180
41. Chokphukiao, Pakwipa et al. "Validity and reliability of the block method for measuring thoracic hyperkyphosis." *Physiotherapy theory and practice*, 1-8. 7 Sep. 2021, doi:10.1080/09593985.2021.1975335