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Correlation Between Hyper kyphosis and Risk of Fall in Geriatric Population

Dianne Gonsalves[1], Dr. Afreen Shaikh[2], Dr. Albin Jerome[3]

[1]Intern, Department of Physiotherapy, St.Andrews College Of Physiotherapy
[2]Assistant Professor, Department of Physiotherapy, St.Andrews College Of Physiotherapy
[3]Principal, Department of Physiotherapy, St.Andrews College Of Physiotherapy

Abstract

Background:

Hyperkyphosis, an excessive forward curvature of the thoracic spine, is common among older adults and has been associated with impaired posture, reduced balance, and increased risk of falls. Falls are a major cause of morbidity and loss of independence among the geriatric population.

Methods:

An observational study was conducted on 62 community-dwelling older adults aged ≥60 years. Participants were screened using the Falls Efficacy Scale–International (FES-I), and those scoring 16–19 (low concern for falls) were included. Hyperkyphosis was assessed using the Flexicurve Ruler to calculate the Kyphotic Index (KI). Balance and risk of fall were assessed using the Functional Reach Test (FRT). KI and FRT data were not normally distributed hence Spearman's rank correlation was used.

Results:

The mean KI was 16.75 ± 2.52, and the mean FRT score was 20.70 ± 3.81 cm. A strong, statistically significant negative correlation was observed between KI and FRT ($r = –0.995$, $p < 0.001$), indicating that an increase in thoracic curvature is associated with reduced functional reach and greater fall risk.

Conclusion:

Hyperkyphosis is strongly associated with impaired balance and increased risk of fall in the geriatric population. Early screening and targeted physiotherapy interventions aimed at postural correction and balance enhancement may help prevent falls and improve functional independence.

Keywords: Hyper kyphosis, Kyphotic Index, Functional Reach Test, Falls, Geriatric Population, Posture

1. INTRODUCTION

Geriatric age group is classified into the following three groups. Adults who are between 65 to 75 years are 'youngest-old'. Those adults who are between 75 to 84 years fall under the category 'middle-old' and lastly, those adults who have crossed the age of 85 years are classified as 'oldest-old.' [1]

The human spine is divided on the basis of number of vertebrae. Starting from up, there are 7 cervical vertebrae, 12 thoracic vertebrae. After which there are 5 lumbar vertebrae and there are 5 fused sacral vertebrae. At the end of the spine, there are 3 to 5 fused coccyx vertebrae. The thoracic spine exhibits a certain degree of kyphosis, while the cervical and lumbar spines exhibit varying degrees of lordosis in a typical human spine. In contrast to lordosis, which is defined as an increase in the backward curvature of the spine along the sagittal plane, kyphosis is an increase in the forward curvature of the spine along the

same plane. We refer to this condition as hyperkyphosis when the forward curvature becomes excessive. The biomechanics influencing spinal curvature are primarily determined by the shape of the vertebral body and intervertebral disc, where an anterior wedge contributes to a greater kyphotic angle. Generally, hyperkyphosis becomes more pronounced with age, particularly after 40, and affects approximately 20% to 40% of adults aged 60 and above. While both genders experience this condition, the rate of increase is notably higher in females, especially during the menopausal transition.[2]

Excessive forward curvature of the thoracic spine, associated with hyperkyphosis related to ageing, can cause a major decline in health. Low well-being scores, poor balance, and an increased risk of mortality have all been linked to hyperkyphosis. Although the exact causes of increased thoracic kyphosis with ageing are unknown, a growing amount of evidence points to vertebral degeneration—such as changes in the shape of the vertebral body that resemble wedges and dehydration of the intervertebral disc—as the main contributing factor. Age-related muscle weakening and general deconditioning, especially of the trunk extensors, may also be factors in spinal postural malalignment and decreased segmental mobility.[4]

An unintentional change in position that causes one to come to rest at a lower level or on the ground was defined as a fall. A significant majority of adults aged 65 and older experience at least one fall annually. Fifty percent of fall incidents result in serious injuries, which have detrimental effects on patients and society as a whole. A patient's deconditioning results from their activity being regulated out of fear of falling. Lower quality of life is the outcome of deconditioning, which increases fall risk. In addition, after being admitted to the hospital for a fall-related injury, patients reside in nursing homes three times more frequently than for other reasons.[4]

A balance disorder is one of the most significant risk factors for falls. Thoracic hyperkyphosis, or an excessive curvature of the thoracic spine, can affect balance. If there is insufficient compensation in the lumbar spine and hip region, hyperkyphosis may cause the body's centre of mass to shift forward, leading to gait abnormalities and imbalance.[4] Changes in the kyphosis angle over time can alter the body's center of mass, potentially impairing balance and increasing the risk of falls.[4] Hyperkyphosis can lead to a variety of negative outcomes, such as impaired respiratory function, restricted spinal motion, fractures, back pain, injurious falls, and mortality.[5]

Greater thoracic curvature alters the normal sagittal alignment of the spine, which can contribute to pain and functional problems in the shoulder and pelvic girdles, as well as in the cervical, thoracic, and lumbar regions. Hyperkyphosis is often accompanied by forward head posture, scapular protraction, reduced lumbar lordosis, and decreased standing height. These postural alterations increase the flexion bias around the hip and shoulder joints, which can disrupt normal joint mechanics and movement patterns.[6]

Evidence suggests that increased thoracic curvature is related to higher mortality, and greater kyphosis severity further amplifies this association.More specifically, the decline in vital capacity seen in individuals with hyperkyphosis has been identified as a predictor of pulmonary-related deaths, especially among older women living in the community.[6]

While vertebral fractures are often considered the primary cause of age-related hyperkyphosis, studies indicate that only about 40% of men and women with severe hyperkyphosis have vertebral compression or wedge fractures. A common radiographic finding among older adults with hyperkyphosis is degenerative disc disease. Existing research consistently indicates that hyperkyphosis is linked to diminished strength of the spinal extensor musculature.[6] Age-related declines in the somatosensory, visual, and vestibular systems likely contribute to the loss of upright postural control. In elderly adults, the percep-

tion of vertical alignment becomes impaired due to a reduction in proprioceptive and vibratory input from the lower extremity joints. Furthermore, age-related deterioration in the visual system further diminishes visual acuity, thereby contributing to postural control issues. Addressing hyperkyphosis is crucial for improving the quality of life and reducing the risk of severe complications in older adults.[6]

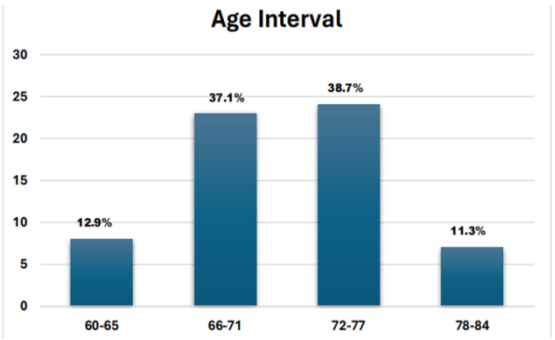
2. Materials and Methodology

This observational cross-sectional study was carried out over a period of six months among community-dwelling older adults residing in Pune, Maharashtra. A total of 91 individuals aged 60 years and above were initially screened through community visits, senior citizen clubs, residential societies, and public areas frequently attended by older adults. Out of these, 62 participants met the inclusion criteria and were recruited using a convenience sampling method. The sample size was calculated using an odds ratio of 2.11, a confidence interval of 95%, and a power of 80%, ensuring adequate strength for detecting a significant correlation between variables. Participants were included if they were 60 years or above, able to stand without the use of any assistive device, and obtained a Falls Efficacy Scale–International (FES-I) score between 16 and 19, indicating a low level of fear of falling and demonstrated a Kyphotic Index (KI) greater than 13, which confirms the presence of hyperkyphosis. Individuals were excluded if they had neurological conditions such as Parkinson's disease, stroke, or cerebellar ataxia; had sustained an orthopedic injury or fracture in the past three months; had undergone recent surgeries affecting mobility; had received physiotherapy interventions related to balance; had a history of fall within the past six months; or were currently experiencing vertigo or using sedative medications that could bias balance assessment. Ethical clearance was obtained prior to recruitment, and all participants provided informed consent.

After demographic data such as age, gender, and activity level were recorded, each participant underwent a standardized kyphosis and balance assessment. Hyperkyphosis was measured using the Flexicurve Ruler, a validated and reliable non-invasive instrument commonly used for assessing thoracic spine curvature. The participant stood barefoot in their natural relaxed posture, and the Flexicurve was molded along the contour of the thoracic spine, extending from the seventh cervical vertebra (C7) to the twelfth thoracic vertebra (T12). This contour was carefully traced onto graph paper, and thoracic width and length were measured. The Kyphotic Index was then calculated using the formula: (thoracic width / thoracic length) × 100. Higher values indicated greater forward curvature. The Functional Reach Test (FRT) was used to assess dynamic balance and fall risk. In this test, the participant stood sideways against a wall with their dominant arm flexed to 90 degrees at shoulder level. The starting position of the middle finger was marked, and participants were instructed to reach forward as far as possible without stepping or losing balance. The distance between the initial and final reach positions was recorded in centimeters. A smaller reach distance indicated greater balance impairment and higher fall risk, based on established cutoff values: <15.24 cm representing high risk, 15.24–25.40 cm moderate risk, and >25.40 cm low risk. All assessments were performed by the same investigator to reduce inter-rater variability. The collected data were first organized in Microsoft Excel and subsequently processed using statistical software. The Kolmogorov–Smirnov test was used to assess normality, which revealed non-normal distribution for KI and FRT values ($p < 0.001$). Therefore, Spearman's rank correlation coefficient was selected as the appropriate non-parametric test to evaluate the relationship between thoracic curvature and fall risk. A p-value under 0.05 was interpreted as indicating statistical significance.

3. Results

A total of 62 individuals participated in the study, with ages ranging from 60 to 84 years. The distribution revealed that the largest proportion of participants belonged to the 72–77-year age group (38.7%), followed by the 66–71-year group (37.1%), while smaller proportions were seen in the 60–65-year (12.9%) and 78–84-year (11.3%) age groups. This distribution indicates that the majority of the sample fell within the "middle-old" category, an age group known to experience notable degenerative spinal changes and increased susceptibility to postural deviations such as hyperkyphosis.



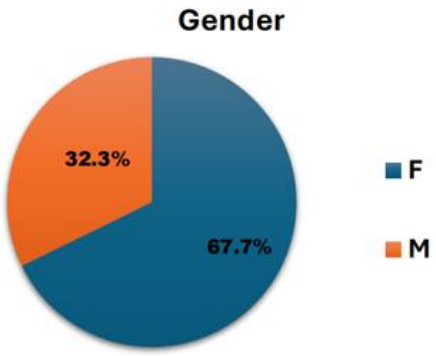
AGE DISTRIBUTION OF PARTICPANTS:

Age Interval		
	Frequency	Percent
60-65	8	12.9 %
66-71	23	37.1 %
72-77	24	38.7 %
78-84	7	11.3 %
Total	62	100.0 %

Gender distribution showed a clear predominance of females, with 42 women (67.7%) and 20 men (32.3%) participating. This pattern is consistent with global epidemiological data indicating that hyperkyphosis is more prevalent in older women due to factors such as menopause-related decline in bone density, vertebral wedging, and accelerated degenerative changes.

GENDER DISTRIBUTION OF PARTICIPANTS:

Gender		
	Frequency	Percent
F	42	67.7%
M	20	32.3%
Total	62	100.0%

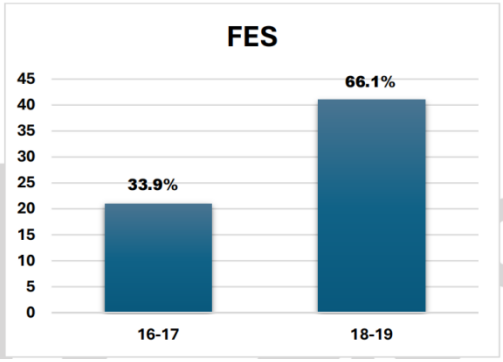


Analysis of fall concern revealed that all participants met the inclusion criteria as per the FES-I score range of 16–19. The mean FES-I score was 17.94 ± 1.10, confirming that the sample represented community-dwelling older adults with low fear of falling, allowing for accurate assessment of kyphosis-

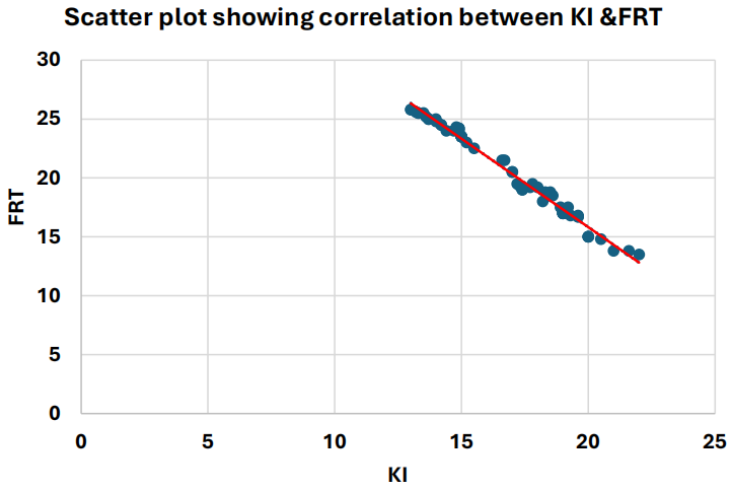
related balance changes without confounding by high fall anxiety. Score distribution showed that 66.1% of participants had scores between 18 and 19, while 33.9% scored between 16 and 17. This consistency indicates minimal psychological bias and strengthens the internal validity of the study.

DISTRIBUTION OF PARTICIPANTS ACCORDING TO FALLS EFFICACY SCALE SCORES

FES		
	Frequency	Percent
16-17	21	33.9%
18-19	41	66.1%
Total	62	100.0%



Thoracic curvature was evaluated through the Kyphotic Index (KI), with a mean value of 16.75 ± 2.52. These values indicate that the majority of participants exhibited mild to moderate degrees of hyperkyphosis, with some showing more pronounced curvature. The variability in KI values reflects natural differences in spinal structure, degenerative patterns, and muscular control in the elderly. Functional balance was assessed using the Functional Reach Test (FRT), yielding a mean reach distance of 20.70 ± 3.81 cm. This score falls within the moderate fall-risk zone and suggests limited dynamic stability in the sample population. The considerable standard deviation indicates variability in balance abilities, reflecting differences in postural control, strength, proprioception, and flexibility among participants.



The distribution of KI and FRT values was evaluated for normality using the Kolmogorov–Smirnov test, and both variables were found to be non-normally distributed ($p < 0.001$). As a result, non-parametric statistical methods were implemented. Spearman's rank correlation analysis revealed a **strong, statistically significant negative correlation ($r = –0.995$, $p < 0.001$)** between the Kyphotic Index and Functional Reach Test scores. This near-perfect negative correlation indicates that as thoracic curvature increased, functional reach decreased proportionately. Participants with the highest kyphotic curvature consistently demonstrated the poorest reach values, indicating compromised dynamic balance and increased susceptibility to fall-related instability. This relationship highlights the biomechanical implications of hyperkyphosis: forward displacement of the center of mass, reduced trunk extensor

strength, altered sensory integration, and limited functional stability—all contributing to decreased reach capacity. Thus, the results strongly support the hypothesis that hyperkyphosis is a significant predictor of reduced balance and elevated fall risk in the geriatric population.

4. Discussion

The present observational study was conducted to examine the correlation between hyperkyphosis and risk of fall in the geriatric population. The aim of the study was to explore how an increase in thoracic spinal curvature affects postural stability and balance among community-dwelling older adults. The study specifically sought to determine the Kyphotic Index (KI) using the Flexicurve Ruler, assess fall risk using the Functional Reach Test (FRT), and establish the relationship between these two variables to understand whether greater spinal curvature corresponds to poorer balance and increased fall risk.

Hyperkyphosis is an abnormal exaggeration of the normal thoracic curvature, often described as an excessive forward bending of the upper back. While mild kyphosis is a natural feature of the thoracic spine, its progression beyond physiological limits results in postural deformity and altered spinal alignment.[2] Normally, the thoracic region of the spine has a natural kyphotic curvature that helps counterbalance the lordotic curves of the cervical and lumbar areas. If this kyphotic curve becomes too pronounced, the body's center of gravity moves forward This biomechanical alteration affects balance, gait, and stability. Age-related degenerative changes in the vertebral bodies, such as anterior wedging, disc dehydration, and weakness of the spinal extensor musculature, contribute to this condition. Hyperkyphosis is therefore not merely a cosmetic change but a significant musculoskeletal and functional problem, particularly among older adults.[6]

Balance refers to the ability to maintain the body's center of gravity over its base of support during static and dynamic activities.[6] It is regulated by the integration of visual, vestibular, and proprioceptive systems, as well as adequate neuromuscular control.[10] In the elderly, these systems gradually deteriorate, making postural control more challenging.[13] When hyperkyphosis develops, the anterior displacement of the trunk further reduces the postural stability margin, demanding greater compensatory muscle activity and joint control.[6] Prolonged strain leads to exhaustion, decreased performance, and increased risk of losing balance and falling.

In this study, 62 geriatric participants aged between 60 and 84 years were assessed. The descriptive statistics revealed a mean Kyphotic Index of 16.75 ± 2.52, indicating a mild to moderate degree of thoracic curvature, while the mean Functional Reach Test score was 20.70 ± 3.81, suggesting moderate dynamic balance ability among participants. The Spearman's correlation analysis showed a strong and statistically significant negative correlation ($\rho = -0.995$, $p < 0.001$) between the Kyphotic Index and Functional Reach Test scores. This indicates that as the severity of thoracic curvature increased, the participant's ability to maintain balance and perform functional reach decreased substantially. Thus, the findings of the present study establish that hyperkyphosis is strongly associated with reduced balance and increased risk of fall in the geriatric population.

These findings are supported by numerous studies in existing literature. McDaniels-Davidson et al. (2017) found that increased thoracic curvature was independently associated with a higher incidence of falls.[7] Koelé et al. (2022) reported that a greater kyphosis angle was linked to poorer physical performance, including reduced muscle strength and balance. Their work emphasized that postural deviations, even when mild, have a considerable influence on stability, corroborating the relationship observed in this study.[4] Further evidence from Katzman et al. (2010) explains that increased curvature shifts the

center of mass anteriorly, increasing flexion bias and disrupting the kinetic chain, resulting in altered muscle recruitment patterns and reduced efficiency of postural control mechanisms [6] Likewise, van der Jagt-Willems et al. (2015) found that older adults with greater thoracic curvature were more likely to experience falls in the following year, highlighting that increased curvature compromises the ability to respond to external disturbances.[9]

In addition, Tran et al. (2016) validated the Flexicurve Ruler, confirming its strong correlation with radiographic Cobb angle measures, which strengthens the methodological reliability of the current study.[18] Jang et al. (2019) further provided evidence that corrective exercises for thoracic hyperkyphosis improve posture, balance, and overall well-being in older women, supporting the potential for physiotherapy interventions to address the deficits observed in this study.[11]

The strong inverse correlation found in this study can be explained by age-related degenerative and neuromuscular changes. As people age, weakening of the spinal extensor muscles and loss of vertebral integrity lead to progressive anterior flexion. This shifts the gravitational line forward, forcing the lower extremity joints to work harder to maintain balance.[6] Due to sarcopenia and delayed neuromuscular responses, these compensatory mechanisms become less effective, leading to instability and reduced functional reach.[13] Moreover, hyperkyphosis is frequently associated with forward head posture, rounded shoulders, and reduced lumbar lordosis, all of which restrict thoracic expansion and limit the ability to correct posture during dynamic movement.[6]

From a clinical standpoint, the results underline the importance of incorporating postural assessment into routine geriatric physiotherapy evaluations.[10] Hyperkyphosis, often viewed as a normal part of aging, represents a modifiable risk factor for falls. Simple, non-invasive tools like the Flexicurve Ruler and Functional Reach Test allow physiotherapists to identify high-risk individuals early and initiate targeted interventions. The present findings support the inclusion of spinal extensor strengthening, postural correction, core stability exercises, and proprioceptive training in rehabilitation programs.

In summary, the present study confirms that thoracic hyperkyphosis significantly affects balance and increases the risk of fall in older adults. The strong negative correlation between Kyphotic Index and Functional Reach Test scores demonstrates that as thoracic curvature increases, balance performance decreases. These findings emphasize that maintaining optimal spinal alignment is crucial for stability and safety in the aging population. Early detection and timely physiotherapy interventions can play a vital role in preventing falls, reducing disability, and enhancing overall well-being.

5. Conclusion

In summary, the present study establishes a strong, statistically significant inverse correlation between thoracic kyphosis and balance ability among older adults. As the severity of kyphotic curvature increases, functional reach and stability decrease, leading to greater susceptibility to falls. The results highlight the need for early detection and management of hyperkyphosis through targeted physiotherapy interventions. Addressing spinal alignment, enhancing muscle strength, and improving proprioceptive control can collectively reduce fall incidence and promote functional independence in the aging population.

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