

## Original Article

# Age Associations with Hamstring Tightness, Trunk Flexibility, and Lumbar Lordosis in Sedentary Adult Females: A Cross-Sectional Study

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## Abstract

**Objectives:** To determine the relationship between age, hamstring tightness, trunk flexibility, and lumbar lordosis angle (LLA), and examine how these variables relate independently of age. Furthermore, we identified the most significant predictor of LLA in sedentary adult females with hamstring tightness. **Methods:** This cross-sectional study included 80 sedentary adult females (20-59 years old) with hamstring tightness, which was assessed using the active knee extension (AKE) and straight leg raising (SLR) tests with a universal goniometer. Trunk flexibility was assessed using the fingertip-to-floor test, and the LLA was evaluated non-radiographically using a flexicurve (flexible ruler). **Results:** A significant correlation was observed between age and all examined variables ( $p < 0.001$ ). Specifically, age was associated with increased fingertip-to-floor distance, suggesting reduced trunk flexibility ( $\beta = 0.756$ ), and increased SLR ( $\beta = 0.517$ ) and AKE ( $\beta = 0.424$ ) angles, indicating increased hamstring tightness. Furthermore, age was the significant independent predictor ( $p < 0.001$ ) of LLA. **Conclusions:** Age is significantly correlated with decreased flexibility and reduced lumbar lordosis angle in adult females. Among the variables examined, age was the significant independent predictor of LLA. These findings highlight the need for early detection and management of age-related musculoskeletal alterations to maintain proper spinal alignment and functional mobility.

**Keywords:** Adult Females, Age Differences, Hamstring Tightness, Lumbar Lordosis, Trunk Flexibility

## Introduction

Flexibility and postural alignment are essential components of musculoskeletal health that influence movement efficiency, functional performance, and postural stability throughout adulthood. Age-related variations in the range of motion (ROM) of joints, muscle flexibility,

and lumbar lordosis angle (LLA) are well documented, including reduced collagen elasticity, decreased muscle fibre elasticity, and increased connective tissue stiffness, which contribute to progressive declines in flexibility as part of the natural aging process. Moreover, hormonal changes and altered physical activity levels, particularly in adult females, may further exacerbate these musculoskeletal adaptations<sup>1,2</sup>. Recent evidence confirms that the decrease in flexibility accelerates during middle age, particularly after the fifth decade of life, affecting both lower limb extensibility and trunk mobility<sup>3,4</sup>.

Hamstring tightness is one of the most common flexibility impairments, especially in individuals with sedentary lifestyles or age-related reductions in physical activity. A healthcare professional could assume that as age increases, hamstring flexibility decreases. Early childhood is characterised by hamstring tightness, which worsens with

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age<sup>5</sup>. The hamstrings arise from the ischial tuberosity and pass downward to be inserted underneath the knee joint, thereby affecting both the hip and knee joints. Their length and elasticity directly impact LLA and fingertip-to-floor distance, which are vital determinants of postural control and functional mobility in daily activities<sup>6</sup>.

Trunk flexibility, typically assessed through forward bending tests, also progressively declines with aging. Reduced trunk mobility has been linked to degenerative changes in spinal structures, weakened paraspinal musculature, and increased stiffness of the surrounding soft tissues<sup>7,8</sup>. It is also influenced by the extensibility of the posterior chain muscles, including the hamstring and spinal extensor muscles. Limited fingertip-to-floor distance restricts the range of motion, alters spinal loading, and may increase susceptibility to lumbar pain syndromes<sup>9,10</sup>. Recent studies have demonstrated that improved hamstring flexibility, for example, through Pilates or stretching interventions, can modify sagittal spinal curvatures and pelvic alignment, indicating a functional relationship between posterior chain flexibility and lumbar posture<sup>11</sup>. A reduction in fingertip-to-floor distance not only limits functional movement but is also linked to increased mechanical strain in the lumbar region. Therefore, understanding the interrelationship between hamstring length, lumbar lordosis angle, and fingertip-to-floor distance is crucial for both clinical assessment and preventive strategies targeting postural deviations and low back pain<sup>12,13</sup>.

The lumbar lordosis angle may decrease with age due to intervertebral disc degeneration, changes in vertebral morphology, and reduced pelvic mobility<sup>8,14</sup>. Hamstring tightness is also associated with restricted pelvic mobility and increased tilting of the pelvis posteriorly, which in turn can alter the lumbar lordotic curve. The LLA is a significant factor because it affects spinal stress. The strain on the lumbar spine increased steadily with greater flexion when the trunk was flexed forward without the use of additional weights. Increased intervertebral flexion may place more strain on the elastic tissues of the spine and trunk muscles, thereby increasing the risk of injury. It also increases intradiscal pressure and anterior shearing forces<sup>15</sup>.

Previous studies have examined the association between aging and tightness of the hamstring<sup>16</sup>, lumbar spine alignment<sup>17,18</sup>, and fingertip-to-floor distance<sup>19</sup> in healthy adults. Other studies have evaluated the link between reduced hamstring extensibility, fingertip-to-floor distance, and LLA in young individuals<sup>20</sup>, patients with low back pain<sup>21,22</sup>, and athletes<sup>12,15</sup>. However, the findings remain inconsistent, and the relationship between age and these interdependent variables in sedentary adult females with hamstring tightness is still not fully understood. To the best of our knowledge, no previous research has specifically explored how age modulates this relationship in adult females with hamstring tightness, a population that is often subject to unique biomechanical and hormonal factors influencing posture and flexibility. Investigating this relationship across different age categories can provide

valuable insights for physiotherapists, exercise specialists, and clinicians in designing age-specific interventions aimed at maintaining flexibility, preventing postural deviations, and promoting musculoskeletal health in older adults. Therefore, the current study aimed to investigate the correlation between age, hamstring tightness, fingertip-to-floor distance, and LLA, as well as the most predictive variable for lumbar lordosis in sedentary adult females with hamstring tightness.

## Materials and Methods

### Study Design

This cross-sectional study was conducted between August 2023 and March 2024 at Jouf University in Saudi Arabia. Prior to the study, the objectives and procedures of the study were clearly explained to all participants.

### Participants

Participants were recruited through consecutive sampling from students, university staff, and employees at Jouf University via posted announcements, university notice boards, and social media invitations. They were selected according to the following inclusion criteria: aged 20–59 years, exhibiting at least a 20° limitation during the active knee extension (AKE) test or straight leg raising (SLR) test, and maintaining a sedentary lifestyle characterised by sitting for at least 6 hours per day, as assessed using the Arabic version of the International Physical Activity Questionnaire-Short Form (IPAQ-SF)<sup>23</sup>. The exclusion criteria included participants experiencing low back, pelvic, or knee pain during evaluation; those classified as obese (BMI  $\geq$  30); individuals with a history of lower extremity or lumbar fractures; a leg length discrepancy exceeding 2.0 cm; tightness of hip flexors; those who had undergone any muscular surgery in the previous year; pregnancy; and women who had given birth in the last year. A total of 92 individuals were screened, of whom 12 were excluded for not meeting the inclusion criteria (three with low back pain, seven classified as obese, and two pregnant), resulting in a final sample of 80 adult females who participated in the current study.

### Sample Size

A priori sample size calculation was conducted using G-power software (Franz Faul, Universität Kiel, Germany) (version 3.1.9.2) for the multiple linear regression analysis. Based on a prior study that reported  $R^2=0.137$ <sup>24</sup>, the effect size was determined using the formula  $f^2=R^2/(1-R^2)$ , resulting in  $f^2=0.15$ , which corresponds to a medium effect size according to Cohen's conventions. Consequently, this study was designed to detect moderate multivariable associations. The targeted statistical power ( $1-\beta$ ) was 0.80, with a significance level of  $\alpha = 0.05$ , and the model included four predictors. The required sample size was 80.

## Procedures

Demographic data were collected from all participants. Height and weight measurements were obtained prior to the evaluation examinations. A single, experienced physical therapist conducted all goniometric assessments during the flexibility examination. Before data collection, the participants were familiarised with the study environment and procedures for each test. Comprehensive instructions were provided and practiced while the participants were positioned appropriately for each test.

### Active Knee Extension (AKE) Test

The active knee extension (AKE) test was used to evaluate hamstring tightness at the knee level. The AKE test exhibits high intra-rater reliability, with an intraclass correlation coefficient (ICC) ranging from 0.87 to 0.94<sup>25</sup>. The participants were instructed to flex their right hip and knee to 90° while in the supine position. They were directed to maintain their foot in plantar flexion to prevent unfavourable neutral tension and extend their right leg as far as possible. A universal goniometer (Physiomed, Manchester, UK) was used to measure the deficit in knee extension from a full 180°, with larger AKE values indicating increased hamstring tightness. Measurements were taken after the final position was maintained for 5 s. The goniometer axis was positioned on the lateral aspect of the knee joint, the stationary arm was aligned with the femur, and the moving arm was aligned with the fibula. Both right and left knees were assessed using the AKE test. The criteria for hamstring muscle soreness were applied to determine the endpoint of the AKE test. Each leg underwent three trials, and the average of the three trials for each side was calculated. The mean value for both legs was used for statistical analysis<sup>26</sup>.

### Straight Leg Raising Test (SLR)

The straight leg-raising test was employed to evaluate hamstring tightness at the hip level. This test demonstrates high intra-rater reliability, with an ICC ranging from 0.93 to 0.97<sup>25</sup>. During the procedure, the participants were instructed to flex the hip joint from the supine position while maintaining knee extension. A standard goniometer was positioned on the greater trochanter of the femur, with the fixed arm aligned along the midline of the trunk and the moving arm directed toward the lateral malleolus of the same leg. The examiner requested the participant to cease hip flexion and measured the degree of limitation if the knee began to flex or if the participant experienced a stretch in the lower back or posterior thigh. The SLR angle indicates the limitation of hip flexion relative to 90°, with higher SLR deficits indicating greater hamstring tightness. The test was conducted three times to ensure accuracy, and the mean values were used for statistical analysis<sup>27</sup>.

### Fingertip-to-floor Distance

This test was used to assess the flexibility of the posterior chain, providing insights into the mobility of the pelvis and spine as the participants flexed forward in the orthostatic position. This test demonstrates a high level of inter-rater reliability, with an ICC of 0.99<sup>28</sup>. Participants were instructed to stand with their feet together on the floor. Subsequently, they were directed to keep their knees, arms, and fingers fully extended and lean their trunk forward as far as possible while maintaining a relaxed neck. A tape measure was used to record the distance in centimetres between the participant's right-hand third finger and the ground in this position. A zero-value indicated that the fingertip reached the ground, whereas positive values indicated that the fingers did not reach the ground. Participants who could easily touch the ground were permitted to stand on a platform approximately 30 cm high, and the measurement was repeated, recording negative values from the top. However, in this study, no participant easily touched the floor; therefore, no negative values were recorded. Consequently, higher values reflect greater limitations in the trunk flexion. The mean value was determined after three repetitions<sup>29</sup>.

### Flexicurve-Derived Lumbar Lordosis Angle (FDLLA)

The flexible ruler is a noninvasive, cost-effective, and reliable alternative to the radiological Cobb method. This technique is regarded as an estimate analogous to the radiological Cobb angle, as several studies have confirmed the instrument's validity and reliability in the thoracic and lumbar regions, demonstrating a significant correlation between this method and the radiological Cobb angle technique<sup>30,31</sup>. For this purpose, the T12 spinous process and sacral base were identified and marked with a removable marker in subjects standing in a relaxed posture. A flexible ruler was applied over the spinous processes from T12 to S2 in the participants' lumbar lordotic angle (LLA). The curve of the flexible ruler was traced onto a paper, representing the shape of the LLA for each participant, with two reference points for T12 and S2. This method exhibits high inter-tester reliability<sup>32</sup>. A vertical line (L) was drawn to represent the total length of the curvature by connecting the labelled marks. A perpendicular line (H), representing the height of the lumbar curve, bisected line L. The length of each line was measured in centimetres, and these values were used in the following formula to calculate the degree of lumbar lordosis ( $\theta$ ):  $\theta = 4 \times [\text{arc tan} (2H/L)]$ <sup>33</sup>.

## Statistical Analysis

The participants' demographic characteristics and collected data were analysed using descriptive statistics. Pearson's correlation coefficient was used to assess the relationships between age, fingertip-to-floor distance, SLR, AKE, and FDLLA. Prior to analysis, the assumptions

**Table 1.** Participant characteristics.

	Mean $\pm$ SD	Maximum	Minimum
Age (years)	39.65 $\pm$ 11.64	59	20
Weight (kg)	63.81 $\pm$ 6.09	76.30	47
Height (cm)	161.24 $\pm$ 4.54	174	152
BMI (kg/m <sup>2</sup> )	24.58 $\pm$ 2.18	28.9	18.59

*SD, Standard deviation; Units: age (years), weight (kg), height (cm), BMI (kg/m<sup>2</sup>).*

**Table 2.** Descriptive statistics of the fingertip-to-floor distance, SLR, AKE, and FDLLA of the participants.

	Mean $\pm$ SD	Minimum	Maximum
Fingertip-to-floor distance (cm)	20.41 $\pm$ 10.35	3.00	44.00
SLR (degrees)	36.03 $\pm$ 8.24	22.30	58.00
AKE (degrees)	43.28 $\pm$ 8.28	26.80	65.00
FDLLA (degrees)	30.44 $\pm$ 8.54	12.00	49.00

*SD, Standard deviation; Units: fingertip-to-floor distance (cm); SLR, straight leg raising (degrees); AKE, active knee extension (degrees); FDLLA, flexicurve-derived lumbar lordosis angle (degrees).*

underlying Pearson's correlation were verified and satisfied; the variables exhibited an approximate normal distribution, as determined by Q-Q plots, and histograms. Linear relationships between the variable pairs were confirmed using scatter plot analysis. Simple linear regression was used to evaluate the effect of age on each dependent variable (fingertip-to-floor distance, SLR, AKE, and FDLLA), whereas multiple regression analysis was conducted to ascertain the combined influence of age, fingertip-to-floor distance, SLR, and AKE on FDLLA. The assumptions for regression analysis were verified and met; residuals were approximately normally distributed, linearity and homoscedasticity were confirmed by inspection of residual plots and normal probability plots. The significance level for statistical testing was set at  $p < 0.05$ . All statistical analyses were performed using the Statistical Package for Social Studies (SPSS) version 25 for Windows (IBM SPSS, Chicago, IL, USA).

## Results

### Subject

In this study, a total of eighty female participants aged 20–59 years were included. The mean  $\pm$  standard deviation (SD) for age, weight, height, and body mass index (BMI) were 39.65  $\pm$  11.64 years, 63.89  $\pm$  6.09 kg, 161.24  $\pm$  4.54 cm, and 24.58  $\pm$  2.18 kg/m<sup>2</sup>, respectively. The demographic characteristics of the participants are presented in Table 1.

### Fingertip-to-floor Distance, SLR, AKE, and FDLLA in the Study Group

Table 2 presents the descriptive statistics for the fingertip-to-floor distance, straight leg raise (SLR), active knee extension (AKE), and Flexicurve-derived lumbar lordosis angle (FDLLA). The fingertip-to-floor distance scores ranged from 3.00 to 44.00. SLR had a mean of 36.03 degrees (range 22.30–58.00 degrees), and AKE had a mean of 43.28 degrees (range 26.80–65.00 degrees), respectively, indicating variability in hamstring flexibility among participants, with higher degrees signifying greater hamstring tightness. The FDLLA ranged from 12.00 to 49.00 degrees.

### Correlation Between Age, Fingertip-to-floor Distance, SLR, AKE, and FDLLA

The analysis revealed a strong positive correlation between age and fingertip-to-floor distance ( $r = 0.756$ ,  $p = 0.001$ ). Additionally, age demonstrated a moderate positive significant correlation with SLR ( $r = 0.517$ ,  $p = 0.001$ ) and AKE ( $r = 0.424$ ,  $p = 0.001$ ). However, a strong negative significant association was observed between age and FDLLA ( $r = -0.728$ ,  $p = 0.001$ ) (Table 3).

### Correlation Between FDLLA, Fingertip-to-floor Distance, SLR, and AKE

FDLLA was strongly negatively correlated with fingertip-to-floor distance ( $r = -0.707$ ,  $p = 0.001$ ) and moderately negatively correlated with SLR ( $r = -0.541$ ,  $p = 0.001$ ) and AKE ( $r = -0.532$ ,  $p = 0.001$ ) (Table 3).

**Table 3.** Correlation between age, fingertip-to-floor distance, SLR, AKE, and FDLLA.

	Age (years)		FDLLA (degrees)	
	r value	p value	r value	p value
Fingertip-to-floor distance (cm)*	0.756	0.001	-0.707	0.001
SLR (degrees)	0.517	0.001	-0.541	0.001
AKE (degrees)	0.424	0.001	-0.532	0.001
FDLLA (degrees)	-0.728	0.001		

*r value, Pearson correlation coefficient; p value, Probability value; Units: fingertip-to-floor distance (cm); SLR, straight leg raising (degrees); AKE, active knee extension (degrees); FDLLA, flexicurve-derived lumbar lordosis angle (degrees); \*Positive correlation between age and fingertip-to-floor distance indicates greater limitation of trunk flexion with increasing age.*

**Table 4.** Simple linear regression analysis showing the effect of age on fingertip-to-floor distance, SLR, AKE, and FDLLA.

Dependent Variable	Unstandardized Coefficients		Standardized Coefficients	t	P value	95.0% Confidence Interval for B	
	B	Std. Error	$\beta$			Lower Bound	Upper Bound
Fingertip-to-floor distance (cm)	0.67	0.07	0.756	10.19	0.001	0.54	0.80
SLR (degrees)	0.37	0.07	0.517	5.33	0.001	0.23	0.50
AKE (degrees)	0.30	0.07	0.424	4.14	0.001	0.16	0.45
FDLLA (degrees)	-0.53	0.06	-0.728	-9.37	0.001	-0.65	-0.42

*B, Unstandardized coefficient;  $\beta$ , Standardized coefficient; CI, Confidence interval; Units: fingertip-to floor distance (cm); SLR, straight leg raising (degrees); AKE, active knee extension (degrees); FDLLA, flexicurve-derived lumbar lordosis angle (degrees).*

**Table 5.** Multiple linear regression analysis of the predictors of FDLLA:

Predictors variables	Unstandardized Coefficients		Standardized Coefficients	t	P value	95.0% Confidence Interval for B		Collinearity Statistics	
	B	Std. Error	$\beta$			Lower Bound	Upper Bound	Tolerance	VIF
(Constant)	56.25	4.157		13.53	0.001	47.97	64.53		
Age (years)	-0.34	0.086	-0.462	-3.96	0.001	-0.51	-0.17	0.38	2.60
Fingertip-to-floor distance (cm)	-0.19	0.110	-0.232	-1.74	0.09	-0.41	0.03	0.29	3.39
SLR (degrees)	-0.06	0.125	-0.060	-0.50	0.62	-0.31	0.19	0.36	2.76
AKE (degrees)	-0.14	0.132	-0.139	-1.09	0.28	-0.41	0.12	0.32	3.13

*B, Unstandardized coefficient;  $\beta$ , Standardized coefficient; CI, Confidence interval; VIF: Variance Inflation Factor; Units: fingertip-to-floor distance (cm); SLR, straight leg raising (degrees); AKE, active knee extension (degrees); FDLLA, flexicurve-derived lumbar lordosis angle (degrees).*

#### Effect of Age on Fingertip-to-floor distance, SLR, AKE, and FDLLA

Simple linear regression analyses were conducted to assess the impact of age on the fingertip-to-floor distance, SLR, AKE, and FDLLA. Age was a significant predictor of

all variables ( $p < 0.001$ ). Age was associated with higher fingertip-to-floor distance scores ( $\beta = 0.756$ ), greater SLR, indicative of increased tightness ( $\beta = 0.517$ ), and elevated AKE, reflecting heightened tightness ( $\beta = 0.424$ ). In contrast, age was strongly negatively correlated with FDLLA ( $\beta = -0.728$ ) (Table 4).

### Effects of Age, Fingertip-to-floor Distance, SLR, and AKE on FDLLA

Multiple linear regression analysis was performed to evaluate the combined effects of age, fingertip-to-floor distance, straight leg raise (SLR), and active knee extension (AKE) on Flexicurve-derived lumbar lordosis angle (FDLLA). The overall model demonstrated statistical significance ( $p < 0.001$ ), with an  $R^2$  value of 0.607, an adjusted  $R^2$  of 0.586, and an F-statistic of 28.94 with degrees of freedom ( $df = (4, 75)$ ), indicating that approximately 60.7% of the variance in FDLLA was accounted for by the four predictors. Among these predictors, age emerged as the significant independent predictor ( $\beta = -0.462$ ,  $p < 0.001$ ), suggesting that an increase in age was associated with a decrease in FDLLA. In contrast, the fingertip-to-floor distance ( $\beta = -0.232$ ,  $p = 0.09$ ), SLR ( $\beta = -0.060$ ,  $p = 0.62$ ), and AKE ( $\beta = -0.139$ ,  $p = 0.28$ ) were not statistically significant predictors (Table 5).

Collinearity diagnostics revealed no evidence of problematic multicollinearity among the predictors. Tolerance values ranged from 0.29 to 0.38, and the corresponding VIF (Variance Inflation Factor) values ranged from 2.60 to 3.39, all within acceptable limits (tolerance  $> 0.20$ ; VIF  $< 5$ ) (Table 5). These findings suggest that the predictors did not excessively share variance or inflate standard errors. However, some degree of shared variance between age and flexibility measures was observed, such that multicollinearity reduces their apparent independent contribution in the multivariable model.

## Discussion

The findings indicated a significant association between age and hamstring tightness, fingertip-to-floor distance, and FDLLA measurements. This study found that older age was associated with greater hamstring tightness, increased fingertip-to-floor distance, and lower FDLLA. Among all variables, age was the significant independent predictor of FDLLA.

Aging was associated with increased hamstring tightness, as shown by the SLR (increased limitation in hip flexion) ( $r = 0.517$ ,  $\beta = 0.517$ ) and AKE (increased deficit in full knee extension) ( $r = 0.424$ ,  $\beta = 0.424$ ). These findings may be attributed to age-related variations, including changes in muscle-tendon tissue properties (increased stiffness and shorter fascicles), reduced physical activity, prolonged sitting, and altered neural tension<sup>24</sup>. These results are consistent with those of Akinpelu et al.<sup>16</sup>, who observed an increase in hamstring tightness in healthy adults from childhood to the age of 40–49 years. Additionally, Mistry et al.<sup>5</sup>, Guzmán-Muñoz et al.<sup>34</sup>, and Moorthy et al.<sup>35</sup> reported a significant negative correlation between age and hamstring flexibility, with lower flexibility observed in the 30–39 and 40–49 age groups than in younger cohorts.

Increasing age was associated with a greater limitation in fingertip-to-floor distance ( $r = 0.756$ ,  $\beta = 0.756$ ). These

findings may be explained by an age-related decline in lumbar ROM, which typically begins at approximately 50 years of age<sup>36</sup> due to decreased water content in the intervertebral disc, increased spinal stiffness<sup>37</sup>, and deterioration of ligamentous viscoelasticity<sup>38</sup>. These changes, along with delayed neuromuscular responses and reduced trunk muscle activation, contribute to mobility limitations in older adults<sup>19,39</sup>. Reduced hamstring flexibility restricts anterior pelvic rotation and lumbopelvic rhythm, thereby increasing the stress on the lumbar spine<sup>40</sup>. These results align with those of Kienbacher et al.<sup>19</sup>, who reported that aging affects the activation patterns of the lumbar extensor muscles and trunk ROM during trunk flexion-extension activities. Furthermore, Medeiros et al.<sup>41</sup> suggested that age-related mobility is joint-specific and potentially linked to different utilisation patterns of body joints throughout life.

Our findings indicate that FDLLA decreases with age ( $r = -0.728$ ,  $\beta = -0.728$ ). In younger adults, variations in hamstring extensibility may have a minimal impact on lumbar lordosis due to greater muscular elasticity, neuromuscular control, and adaptable spinal alignment, which facilitate the maintenance of a neutral curve in the lumbar spine<sup>42</sup>. However, older adults are more prone to reduced lumbar lordosis due to age-related degenerative disc height loss, weakening of the lumbar extensors, and adaptive postural changes<sup>8</sup>. Hamstring tightness may influence lumbar curve alignment by inducing a posterior pelvic tilt<sup>43</sup>, leading to compensatory spinal mechanics, increased spinal stress, and heightened injury risk<sup>44</sup>. These findings are corroborated by Youdas et al.<sup>17</sup> and Lang-Tapia et al.<sup>45</sup>, who identified a correlation between LLA and age, particularly in the 20–29 and 50–59 age groups. Asad et al.<sup>18</sup> observed that LLA in relaxed standing was reduced in individuals aged 31–60 years compared to those below 30 years.

Our results demonstrated a strong negative correlation between FDLLA and reduced fingertip-to-floor distance ( $r = -0.707$ ), as well as moderate negative correlations with hamstring tightness, as measured by SLR ( $r = -0.541$ ) and AKE ( $r = -0.532$ ). These findings suggest that a decreased LLA is associated with reduced trunk mobility and increased hamstring tightness. This supports evidence that reduced lumbar lordosis alters posterior chain biomechanics, thereby increasing hamstring strain and limiting forward flexion<sup>10,46</sup>. These findings are consistent with those of Scannell and McGill<sup>47</sup> and Hsu et al.<sup>48</sup>, who reported a relationship between LLA and sagittal lumbar flexibility affecting trunk ROM. Rodríguez-García et al.<sup>49</sup>, López-Miñarro et al.<sup>50</sup>, and McCarthy and Betz<sup>51</sup> reported a correlation between hamstring tightness and LLA during maximal trunk forward flexion tasks with extended knees. However, these studies did not demonstrate such a relationship between hamstring tightness and lumbar lordosis in other age groups.

The findings illustrate that age, hamstring tightness, and fingertip-to-floor distance contribute to changes in the LLA. However, age emerged as the significant predictor, exhibiting a negative association with FDLLA ( $\beta = -0.462$ ),

suggesting that increasing age is more closely related to decreased lumbar lordosis than to hamstring tightness and fingertip-to-floor distance. The effect of age aligns with evidence indicating age-related alterations in spinal morphology<sup>8</sup>, resulting in a reduction in LLA<sup>52</sup>.

### Clinical Implications

Our results highlight the importance of early assessment of age-related changes in hamstring flexibility, trunk flexibility, and LLA among sedentary females with hamstring tightness. Since age has a strong relationship with these outcomes and is the significant predictor of LLA, clinicians should prioritise regular evaluation of the flexibility and alignment of the lumbar spine, especially in sedentary females. Early recognition can direct specialised treatment programs, such as hamstring stretching, lumbar extensor strengthening, and postural exercises, to help maintain ideal lumbopelvic mechanics. These preventive measures may decrease the risk of functional restrictions, back pain, and degenerative alterations with increasing age.

### Limitations and Recommendations

Several limitations must be considered when interpreting the findings of this study. First, the sample comprised only adult women, restricting the generalisability of the findings to men or younger populations. Second, spinal measurements were static, and dynamic lumbar-pelvic movement was not assessed; evaluating the movement patterns could provide a more comprehensive understanding of functional biomechanics. Third, although sedentary behaviour was measured using the IPAQ-SF, a validated self-report instrument, questionnaires may be susceptible to recall bias, and objective measures such as accelerometry were not used. Fourth, although age emerged as the significant predictor of the lumbar lordosis angle, it likely represents a combination of processes, including degenerative changes, physical activity patterns, and hormonal influences that cannot be distinguished in this cross-sectional design. Finally, other relevant factors, such as imaging assessments or clinical history (menopausal status, parity, physical activity beyond sitting hours, occupational load, and history of low back pain), were not included, limiting our insight into the mechanisms affecting spinal alignment. Future studies should include longitudinal research to better understand the age-associated modifications in LLA and flexibility. Research should encompass diverse populations, including males and individuals with varying physical activity levels, to enhance the generalisability of the findings. Incorporating dynamic movement analysis and muscle strength assessments would provide an understanding of the factors influencing lumbar alignment. Researchers should examine physical activity using objective methods, as it may influence flexibility and LLA. Further studies are needed to evaluate the mechanisms underlying age-related changes in lumbar spinal alignment. Future research should

incorporate imaging assessments and detailed clinical histories to provide a comprehensive understanding of the factors influencing lumbar spinal alignment.

## Conclusion

In conclusion, in sedentary adult females with hamstring tightness, advancing age was significantly correlated with increased limitations in fingertip-to-floor distance and increased hamstring tightness. Additionally, age was strongly negatively correlated with the flexicurve-derived lumbar lordosis angle, indicating a reduction in lumbar lordosis with increasing age. Although initial correlations were observed between flexibility measures and the lumbar lordosis angle, multiple regression analysis identified age as the significant independent predictor. These findings suggest that, within this population, age-related factors are more closely associated with diminished lumbar lordosis than with flexibility limitations. Clinicians should consider age when evaluating posture, interpreting flexibility assessments, and devising interventions for this demographic.

### Ethics Approval

*The study was approved by Al Qurayyat Health Affairs, Jouf Region (Project No. 60/2023) and conducted in accordance with the 1964 Declaration of Helsinki and its later amendments.*

### Consent to Participate

*All participants provided written informed consent prior to participation.*

### Authors' Contributions

*NMA, NZA, and TAA contributed to the design, conceptualization of the study. TAA, TNA, AAA, and RNA engaged in data collection. KTA, AMA, TMA, NSA, and MHA aided in the data analysis and interpretation. NMA, TAA, TNA, AAA, RNA, NSA, and MHA participated in writing, review and editing. All authors read and approved the final version of the manuscript.*

## References

1. Gutiu RI, Serban O, Badarinza M, Pelea MA, Abdulrahman I, Fodor D. Muscle elasticity variations in assessing age-related changes in adults—A systematic review. *Geriatr Gerontol Int* 2025;25: 855-63.
2. Youdas JW, Krause DA, Hollman JH, Harmsen WS, Laskowski ER. The influence of gender and age on hamstring muscle length in healthy adults. *JOSPT* 2008;38(5):356–62.
3. Palmer TB, Thompson BJ. Influence of age on passive stiffness and size, quality, and strength characteristics. *Muscle & nerve* 2017;55(3):305-15.
4. Wilke J, Macchi V, De Caro R, Stecco C. Fascia thickness, aging and flexibility: is there an association?. *J Anat* 2019;234(1):43-9.
5. Mistry GS, Vyas NJ, Sheth MS. Correlation of

- hamstrings flexibility with age and gender in subjects having chronic low back pain. *IJTR* 2014;3(4):31-8.
6. Rodgers CD, Raja A. Anatomy, bony pelvis and lower limb, hamstring muscle. StatPearls. Treasure Island (FL): StatPearls Publishing; 2022.
  7. Patel P, Parmar L. Normative values of trunk mobility in normal adults. *Int J Health Sci* 2022;6(S4):6171-9.
  8. Dreischarf M, Albiol L, Rohlmann A, Pries E, Bashkuev M, Zander T, Duda G, Druschel C, Strube P, Putzier M, Schmidt H. Age-related loss of lumbar spinal lordosis and mobility—a study of 323 asymptomatic volunteers. *PLoS one* 2014;9(12):e116186.
  9. Nikzad S, Pirouzi S, Taghizadeh S, Hemmati L. Relationship between hamstring flexibility and extensor muscle activity during a trunk flexion task. *Chiropr Med* 2020;19(1):21-7.
  10. Kang SH. Effects of hamstring flexibility and trunk flexion posture on creep deformation of viscoelastic lumbar tissues: An exploratory study. *Biomech* 2025:112895.
  11. González-Gálvez N, Marcos-Pardo PJ, Trejo-Alfaro H, Vaquero-Cristóbal R. Effect of 9-month Pilates program on sagittal spinal curvatures and hamstring extensibility in adolescents: randomised controlled trial. *Sci Rep* 2020;10(1):9977.
  12. Cejudo A, Centenera-Centenera JM, Santonja-Medina F. The potential role of hamstring extensibility on sagittal pelvic tilt, sagittal spinal curves and recurrent low back pain in team sports players: a gender perspective analysis. *Int J Environ Res Public Health* 2021;18(16):8654.
  13. Opplert J, Babault N. Acute effects of dynamic stretching on muscle flexibility and performance: an analysis of the current literature. *Sports Med* 2018;48(2):299-325.
  14. Diebo BG, Varghese JJ, Lafage R, Schwab FJ, Lafage V. Sagittal alignment of the spine: what do you need to know?. *Clin Neurol Neurosurg* 2015;139:295-301.
  15. Lopez-Minarro PA, Alacid F. Influence of hamstring muscle extensibility on spinal curvatures in young athletes. *Sci Sports* 2010;25:188-93.
  16. Akinpelu AO, Bakare U, Adegoke BO. Influence of age on hamstring tightness in apparently healthy Nigerians. *Nig Soc Physiother* 2005;15(2):35-42.
  17. Youdas JW, Hollman JH, Krause DA. The effects of gender, age, and body mass index on standing lumbar curvature in persons without current low back pain. *Physiother Theory Pract* 2006;22(5):229-37.
  18. Asad MR, Amir KM, Jafari FH, Taha M, Sam W. Effect of ageing on lumbar curvature, lumbar mobility, back extensor strength and their relationship with postural stability and clinically relevant low back pain. *Indian J Physiother Occup Therapy* 2014;8(4):271-6.
  19. Kienbacher T, Paul B, Habenicht R, Starek C, Wolf M, Kollmitzer J, Mair P, Ebenbichler G. Age and gender related neuromuscular changes in trunk flexion-extension. *J Neuro Engineering Rehabil* 2015;12(1):3.
  20. Allam NM, Ebrahim HA, Megahed Ibrahim A, Elneblawi NH, El-Sherbiny M, Fouda KZ. The association of hamstring tightness with lumbar lordosis and trunk flexibility in healthy individuals: gender analysis. *Front Bioeng Biotechnol* 2023;11:1225973.
  21. Reis FJ, Macedo AR. Influence of hamstring tightness in pelvic, lumbar and trunk range of motion in low back pain and asymptomatic volunteers during forward bending. *Asian Spine J* 2015;9(4):535.
  22. Arab AM, Nourbakhsh MR. Hamstring muscle length and lumbar lordosis in subjects with different lifestyle and work setting: Comparison between individuals with and without chronic low back pain. *Back Musculoskelet Rehabil* 2014;27(1):63-70.
  23. Al-Hazzaa HM. Health-enhancing physical activity among Saudi adults using the International Physical Activity Questionnaire (IPAQ). *Public Health Nutr* 2007;10(1):59-64.
  24. Abate Daga F, Panzolini M, Allois R, Baseggio L, Agostino S. Age-related differences in hamstring flexibility in prepubertal soccer players: an exploratory cross-sectional study. *Front psychol* 2021;12:741756.
  25. Neto T, Jacobsohn L, Carita AI, Oliveira R. Reliability of the active-knee-extension and straight-leg-raise tests in subjects with flexibility deficits. *Sport Rehabil* 2015;24(4):1-4.
  26. Joshi DG, Balhilla G, Prabhu A. Effect of remote myofascial release on hamstring flexibility in asymptomatic individuals—A randomized clinical trial. *J Bodyw Mov Ther* 2018;22:832-7.
  27. Castellote-Caballero Y, Valenza MC, Puentedura EJ, Fernández-de-Las-Peñas C, Alburquerque-Sendín F. Immediate effects of neurodynamic sliding versus muscle stretching on hamstring flexibility in subjects with short hamstring syndrome. *J Sports Med* 2014;2014(1):127471.
  28. Perret C, Poiraudreau S, Fermanian J, et al. Validity, reliability, and responsiveness of the fingertip-to-floor test. *Arch Phys Med Rehabil* 2001;11(82):1566-70.
  29. Rodrigues E, Pontes AR, Brochado G, Bessa I, Carvalho P, Crasto C. Immediate effects of Global Active Stretching on strength and flexibility: Randomised Controlled Trial. *Afr J Sports Med* 2024;36(1):1-6.
  30. Oliveira TS, Candotti CT, La Torre M, Pelinson PP, Furlanetto TS, Kutchak FM, et al. Validity and reproducibility of the measurements obtained using the flexicurve instrument to evaluate the angles of thoracic and lumbar curvatures of the spine in the sagittal plane. *Rehabil Res Pract* 2012;2012:186156.
  31. Barrett E, McCreesh K, Lewis J. Reliability and validity of non-radiographic methods of thoracic kyphosis measurement: a systematic review. *Man Ther* 2014;19(1):10-7.
  32. Shin SS, Yoo WG. Inter-tester reliability of lumbar lordosis posture classification using a novel screening device. *Manip Physiol Ther* 2021;44(1):35-41.
  33. Arab AM, Talimkhani A, Karimi N et al. Change in

- lumbar lordosis during prone lying knee flexion test in subjects with and without low back pain. *Chiropr Man Therap* 2015;23(1):18.
34. Guzmán-Muñoz E, Zurita-Leiva C, Gómez-Araya F, Concha-Cisternas Y, Castillo-Paredes A, Montalva-Valenzuela F, Yáñez-Sepúlveda R, Jofré-Saldía E, Molina-Márquez I, Vasquez-Muñoz M. Impact of hamstring tightness on muscle activation in healthy young adults. *Funct Morphol Kinesiol* 2025;10(4):363.
  35. Moorthy AS, Karthikeyan T, Singh P. Quantify and influence of age on hamstring tightness in apparently healthy 5 to 59 years old population. *CAIMS* 2018;16(2):163-7.
  36. Intolo P, Milosavljevic S, Baxter DG, Carman AB, Pal P, Munn J. The effect of age on lumbar range of motion: a systematic review. *Man Ther* 2009;14:596-604.
  37. Galbusera F, van Rijsbergen M, Ito K, Huyghe JM, Brayda-Bruno M, Wilke HJ. Ageing and degenerative changes of the intervertebral disc and their impact on spinal flexibility. *Eur Spine J* 2014;23:324-32.
  38. Solomonow M. Sensory-motor control of ligaments and associated neuromuscular disorders. *J Electromyogr Kinesiol* 2006;16:549-67.
  39. Nagai K, Yamada M, Mori S, Tanaka B, Uemura K, Aoyama T, et al. Effect of the muscle coactivation during quiet standing on dynamic postural control in older adults. *Arch Gerontol Geriatr* 2013;56:129-33.
  40. Fasuyi FO, Fabunmi AA, Adegoke BO. Hamstring muscle length and pelvic tilt range among individuals with and without low back pain. *Bodyw Mov Ther* 2017;21(2):246-50.
  41. Medeiros HB, Araújo DS, Araújo CG. Age-related mobility loss is joint-specific: an analysis from 6,000 Flexitest results. *Age* 2013;35(6):2399-407.
  42. Vaquero-Cristóbal R, Molina-Castillo P, López-Miñarro PA, Albaladejo-Saura M, Esparza-Ros F. Hamstring extensibility differences among elite adolescent and young dancers of different dance styles and non-dancers. *Peer J* 2020;8:e9237.
  43. Raffry SM, Marshall PW. Does a 'tight' hamstring predict low back pain reporting during prolonged standing? *J Electromyogr Kinesiol* 2012;22:407-11.
  44. Fatima G, Qamar MM, Hassan JU, Basharat A. Extended sitting can cause hamstring tightness. *Saudi J Sports Med* 2017;17(2):110-4.
  45. Lang-Tapia M, España-Romero V, Anelo J, Castillo MJ. Differences on spinal curvature in standing position by gender, age and weight status using a noninvasive method. *Appl Biomech* 2011;27(2):143-50.
  46. Johnson EN, Thomas JS. Effect of hamstring flexibility on hip and lumbar spine joint excursions during forward-reaching tasks in participants with and without low back pain. *Arch Phys Med Rehabil* 2010;91(7):1140-2.
  47. Scannell JP, McGill SM. Lumbar posture—should it, and can it, be modified? A study of passive tissue stiffness and lumbar position during activities of daily living. *Phys Ther* 2003;83:907-17.
  48. Hsu C, Castillo E, Lieberman D. The relationship between trunk muscle strength and flexibility, intervertebral disc wedging, and human lumbar lordosis. *THURJ* 2015;8(1):35-41.
  49. Rodríguez-García P, López-Miñarro P, Yuste J, Sáinz de Baranda P. Comparison of hamstring criterion-related validity, sagittal spinal curvatures, pelvic tilt and score between sit-and-reach and toe-touch tests in athletes. *Med Dello Sport* 2008;61(1):11-20.
  50. López-Miñarro P, Sáinz de Baranda P, Rodríguez-García PL. A comparison of the sit-and-reach test and the back-saver sit-and-reach test in university students. *J Sports Sci Med* 2009;8(1):116-22.
  51. McCarthy JJ, Betz RR. The relationship between tight hamstrings and lumbar hypo-lordosis in children with cerebral palsy. *Spine* 2000;25(2):211-3.
  52. Ishihara Y, Morishita M, Kanzaki K, Toyone T. Age-related progression of degenerative lumbar kyphoscoliosis: a retrospective study. *Spine Surg Relat Res* 2020;4(3):229-36.