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Relationship Between Lower Limb Muscle Strength and Kyphosis Degree With Fall Risk in Elderly Women: a Cross-Sectional Study

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Abstract: *The growing number of elderly individuals in Indonesia has led to an increased prevalence of physical function impairments, including reduced lower limb muscle strength and postural changes such as kyphosis, both of which are fall risk factors in elderly women. An analytical observational study with a cross-sectional design was conducted on 60 elderly women (≥60 years) selected by purposive sampling from a population of 423 individuals. Lower limb muscle strength was measured using the Back and Leg Dynamometer, kyphosis degree using a flexicurve ruler, and fall risk using the Modified Indonesian Fall Risk Assessment Tool (M-IFRAT). Analysis was performed using Spearman correlation test. The mean respondent age was 67.63 years. The majority had very poor muscle strength (90.0%), 76.7% had normal posture, and 56.7% were classified as high fall risk. There was a significant relationship between lower limb muscle strength and fall risk ($r = -0.618$; $p < 0.001$) and between kyphosis degree and fall risk ($r = 0.553$; $p < 0.001$). Regression analysis showed that both variables together explained 53.4% of fall risk variation ($R^2 = 0.534$). Higher lower limb muscle strength is associated with lower fall risk, while higher kyphosis degree is associated with greater fall risk. Physiotherapy interventions targeting lower limb muscle strengthening and postural correction are recommended as fall prevention strategies for elderly women.*

Keywords: *lower limb muscle strength, kyphosis, fall risk, elderly women, M-IFRAT*

Abstrak: Meningkatnya jumlah lansia di Indonesia telah menyebabkan peningkatan prevalensi gangguan fungsi fisik, termasuk penurunan kekuatan otot tungkai bawah dan perubahan postur seperti kifosis, yang keduanya merupakan faktor risiko jatuh pada lansia wanita. Penelitian observasional analitik dengan desain cross-sectional dilakukan pada 60 lansia wanita berusia ≥60 tahun yang dipilih menggunakan teknik purposive sampling dari populasi sebanyak 423 individu. Kekuatan otot tungkai bawah diukur menggunakan Back and Leg Dynamometer, derajat kifosis menggunakan flexicurve ruler, dan risiko jatuh menggunakan Modified Indonesian Fall Risk Assessment Tool (M-IFRAT). Analisis data dilakukan menggunakan uji korelasi Spearman. Rerata usia responden adalah 67,63 tahun. Sebagian besar responden memiliki kekuatan otot sangat kurang (90,0%), 76,7% memiliki postur normal, dan 56,7% diklasifikasikan memiliki risiko jatuh tinggi. Terdapat hubungan yang signifikan antara kekuatan otot tungkai bawah dan risiko jatuh ($r = -0,618$; $p < 0,001$), serta antara derajat kifosis dan risiko jatuh ($r = 0,553$; $p < 0,001$). Analisis regresi menunjukkan bahwa kedua variabel secara bersama-sama menjelaskan 53,4% variasi risiko jatuh ($R^2 = 0,534$). Kekuatan otot tungkai bawah yang lebih tinggi berhubungan dengan risiko jatuh yang lebih rendah, sedangkan derajat kifosis yang lebih tinggi berhubungan dengan risiko jatuh yang lebih besar. Intervensi fisioterapi yang menargetkan penguatan otot tungkai bawah dan koreksi postur direkomendasikan sebagai strategi pencegahan jatuh pada lansia wanita.

Kata kunci: kekuatan otot tungkai bawah, kifosis, risiko jatuh, lansia wanita, M-IFRAT

Introduction

The increasing life expectancy in Indonesia has continuously expanded the elderly population. Data from the Central Statistics Agency (BPS), as reported by Sitanggang et al. (2024), indicate

that the life expectancy of Indonesians reached 73.5 years in 2021, and Indonesia is projected to become an aging population country by 2050, with an estimated 77 million elderly individuals. This demographic transition is not only reflected in the growing number of older adults, but also in the increasing burden of age-related functional decline. As people age, changes in muscle strength, posture, balance, and mobility may reduce independence and increase vulnerability to falls.

Falls are one of the major health problems among older adults because they may lead to injury, disability, reduced quality of life, and mortality. Globally, approximately 28–35% of individuals aged over 60 years experience falls each year, and this proportion increases to 32–42% among those aged over 70 years (Fadilah et al., 2024). In Indonesia, fall-related injuries among older adults remain a considerable concern, particularly in those aged 65 years and above (Agustiningrum et al., 2023). In Bali, the increasing prevalence of fall risk among the elderly further emphasizes the need for early identification of modifiable risk factors in community settings (Sari et al., 2025).

Elderly women are more vulnerable to falls than men due to physiological changes after menopause. The decline in estrogen levels after menopause contributes to reduced bone mineral density, increased osteoporosis risk, decreased muscle mass and strength, and postural changes such as thoracic hyperkyphosis. These changes may interact with one another and impair postural balance, thereby increasing fall risk among elderly women (Mustafa et al., 2022).

Lower limb muscle strength plays an important role in maintaining postural stability, walking ability, and balance recovery. In elderly women, reduced muscle strength is associated with type II muscle fiber atrophy, neuromuscular junction dysfunction, and hormonal changes. Previous research has shown that elderly women with a history of falls tend to have lower lower-limb extensor strength and slower neuromuscular activation latency, which may reduce their ability to respond quickly to balance disturbances (Li et al., 2024). In addition, thoracic hyperkyphosis may shift the body's center of gravity anteriorly, reduce the efficiency of compensatory balance mechanisms, and increase postural instability during movement (Niibo et al., 2022).

Although lower limb muscle weakness and increased kyphosis degree have both been recognized as fall risk factors, previous studies have generally examined these variables separately. This approach may not fully explain fall risk in elderly women, because balance control is influenced by the interaction between muscular capacity and postural alignment. Therefore, simultaneous assessment of lower limb muscle strength and kyphosis degree is needed to provide a more comprehensive understanding of fall risk, particularly among elderly women in Indonesia.

Pejeng Village, Tampaksiring District, Gianyar Regency, Bali, has 423 elderly women aged ≥60 years, making it a relevant community setting for this study. The novelty of this study lies in

its simultaneous analysis of lower limb muscle strength and kyphosis degree in relation to fall risk among elderly women in a rural Indonesian population. This study aims to analyze the relationship between lower limb muscle strength and kyphosis degree with fall risk among elderly women in Pejeng Village.

Methods

This analytical observational study used a cross-sectional study design and was conducted in four banjars (administrative sub-villages) in Pejeng Village, Tampaksiring District, Gianyar Regency, Bali, from March to May 2026. A cross-sectional study design was chosen because it allows the independent variables, namely lower limb muscle strength and kyphosis degree, and the dependent variable, fall risk, to be measured at the same time without intervention. Therefore, this design was considered appropriate for analyzing the relationship between physical function, postural alignment, and fall risk among elderly women in a community setting.

The target population was elderly women aged ≥60 years residing in Pejeng Village, with an accessible population of 423 individuals. Respondents were selected using purposive sampling based on predetermined inclusion and exclusion criteria. Potential respondents from the four banjars were screened by the researcher through interview, anamnesis, and direct observation of functional ability. The screening included age, residence, ability to communicate verbally, ability to understand and follow simple instructions, ability to stand and walk without assistive devices, history of neurological disorders, and lower limb musculoskeletal conditions.

The sample size was calculated using G*Power version 3.1 with an a priori power analysis. The parameters used were test family = Exact, statistical test = Correlation: Bivariate normal model, two-tailed test, correlation under H1 = 0.387, α error probability = 0.05, power = 0.80, and correlation under H0 = 0. The minimum required sample size was 50 respondents. To anticipate possible drop-out, 20% was added, resulting in a final sample of 60 respondents.

The inclusion criteria were: (1) women aged ≥60 years; (2) residing in Pejeng Village; (3) able to communicate verbally in daily conversation; (4) able to understand and follow simple instructions; and (5) willing to participate by signing informed consent. The exclusion criteria were: (1) using walking aids such as a cane, walker, or wheelchair; (2) having neurological disorders affecting balance or muscle strength, such as stroke, Parkinson's disease, or peripheral neuropathy; and (3) having lower limb musculoskeletal disorders that limited functional activity, such as severe osteoarthritis, lower limb fracture, or severe pain affecting standing and walking ability.

Of the 423 elderly women in the accessible population, 85 potential respondents were present and underwent screening during data collection, while 338 were not available. After screening, 25

respondents were excluded because they used walking aids (n = 11), had neurological disorders (n = 2), or had lower limb musculoskeletal disorders (n = 12). Thus, 60 respondents met the study criteria and were included in the final analysis.

Before data collection, the researcher standardized the measurement procedures to ensure consistency in screening, instrument use, respondent positioning, and score recording. All measurements were conducted using the same procedure for each respondent. Respondents were first informed about the purpose and procedure of each measurement, and safety was ensured before the assessment began.

Lower limb muscle strength was measured using the Back and Leg Dynamometer, which has been reported to have good validity and reliability (Astari et al., 2021). During the measurement, respondents stood on the platform with their feet shoulder-width apart and their body in an upright but relaxed position. The chain and handle length were adjusted according to each respondent's height. Respondents were then instructed to flex their knees to approximately 120° while holding the dynamometer handle with both hands. After the position was stable, respondents pulled the handle upward with maximal effort for approximately three seconds without changing body position. The measurement was performed three times with a short rest interval between trials, and the highest value was recorded as the lower limb muscle strength score.

Kyphosis degree was measured using a flexicurve ruler, which has been used as a valid and reliable instrument for assessing thoracic kyphosis (Kumar, 2022). Respondents were asked to stand upright in a relaxed position. The anatomical landmarks were palpated and marked, and the flexicurve ruler was shaped along the thoracic spinal curvature. The curve formed by the flexicurve ruler was then traced on graph paper. The kyphosis index was calculated using the formula (h/l) × 100 and categorized as normal or hyperkyphosis according to the predetermined cut-off point.

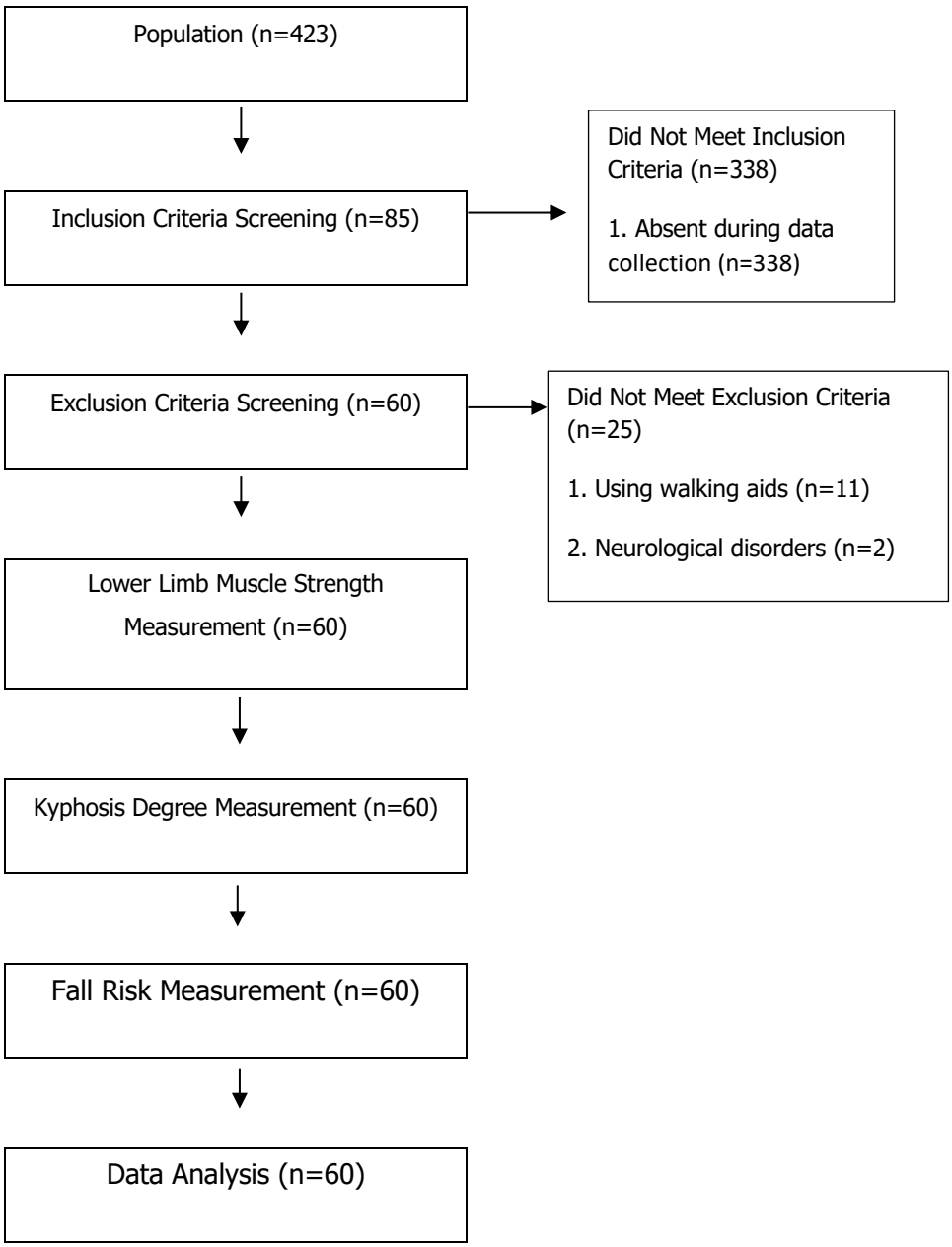
Fall risk was assessed using the Modified Indonesian Fall Risk Assessment Tool (M-IFRAT), a 10-item instrument validated for Indonesian elderly individuals (Nugraha, 2023). The assessment was conducted through a structured interview. Before completing the instrument, the researcher explained each item to ensure that respondents understood the questions. The items assessed several fall-related risk factors, including fall history, physical condition, balance and mobility problems, use of assistive devices, and environmental factors. The total score was calculated, with scores <11 categorized as low fall risk and scores ≥11 categorized as high fall risk.

Data were analyzed using SPSS version 25.0. Univariate analysis was used to describe respondent characteristics and the distribution of lower limb muscle strength, kyphosis degree, and fall risk. Data normality was tested using the Shapiro-Wilk test. Since the lower limb muscle strength and kyphosis degree data were not normally distributed, bivariate analysis was performed

using the Spearman correlation test. Multiple linear regression analysis was then conducted to assess the simultaneous contribution of lower limb muscle strength and kyphosis degree to fall risk. Statistical significance was set at $p < 0.05$.

Results

A total of 60 elderly women from Pejeng Village met the study criteria and were included in the final analysis. The participant recruitment flow is presented in Figure 1 (STROBE-adapted flow diagram).



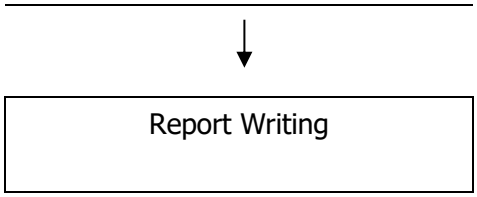


Figure 1. STROBE-adapted flow diagram of study participant recruitment

Respondent Characteristics

Respondent characteristics are presented in Table 1. The mean respondent age was 67.63 years, with the majority in the young-elderly group (60–74 years), totaling 37 individuals (61.7%).

Table 1. Characteristics of Study Subjects (n=60)

Variable	Mean	Category	n	%
Age	67.63	Young-Elderly (60–74 years)	37	61.7
		Middle-Elderly (75–89 years)	23	38.3
		Total	60	100

Distribution of Study Variables

The distribution of study variables is presented in Table 2. The mean lower limb muscle strength was 19.28 kg, with 54 respondents (90.0%) in the very poor category. The mean kyphosis index was 8.15; 46 respondents (76.7%) had normal kyphosis posture. The mean fall risk score was 11.60; 34 respondents (56.7%) were categorized as high fall risk.

Table 2. Distribution of Study Variables (n=60)

Variable	Mean	Category	n	%
Lower Limb Muscle Strength (kg)	19.28	Fair (59–102)	2	3.3
		Poor (44–58.5)	4	6.7
		Very Poor (<44)	54	90.0
Kyphosis Degree (Kyphosis Index)	8.15	Normal	46	76.7
		Hyperkyphosis	14	23.3
Fall Risk (M-IFRAT Score)	11.60	Low Fall Risk (<11)	26	43.3
		High Fall Risk (≥11)	34	56.7

Spearman Correlation Test

The Spearman correlation test results showed a significant relationship between lower limb muscle strength and fall risk ($r = -0.618$; $p < 0.001$), indicating a strong negative relationship: the higher the muscle strength, the lower the fall risk. There was also a significant relationship between kyphosis degree and fall risk ($r = 0.553$; $p < 0.001$), indicating a moderate positive relationship: the higher the kyphosis degree, the higher the fall risk. Full results are presented in Table 3.

Table 3. Spearman Correlation Test Results (n=60)

Variable	Correlation Coefficient (r)	p-value
Lower Limb Muscle Strength ↔ Fall Risk	−0.618	0.000
Kyphosis Degree ↔ Fall Risk	0.553	0.000

Note: $p < 0.05$ is considered statistically significant.

Linear Regression Analysis

Multiple linear regression analysis was conducted to assess the simultaneous contribution of lower limb muscle strength and kyphosis degree to fall risk. Results showed $R^2 = 0.534$, meaning both variables together explain 53.4% of fall risk variation in elderly women. The regression coefficients for muscle strength ($\beta = -0.491$; $p < 0.001$) and kyphosis degree ($\beta = 0.294$; $p = 0.002$) were both statistically significant (Table 4).

Table 4. Multiple Linear Regression Analysis Results (n=60)

Variable	β	R^2	p-value
Lower Limb Muscle Strength	−0.491	0.534	0.000
Kyphosis Degree	0.294		0.002

Note: β = standardized regression coefficient; R^2 = coefficient of determination; $p < 0.05$ is considered statistically significant.

Discussion

Respondent Characteristics

This study involved 60 elderly women from Pejeng Village with a mean age of 67.63 years. Most respondents were categorized as young-elderly, indicating that the study population was dominated by older adults in the early stage of aging. This predominance may be related to the inclusion criteria, which required respondents to be able to stand independently and participate in physical measurements. Older respondents are more likely to experience mobility limitations, use walking aids, or have neurological and musculoskeletal conditions, which may have reduced their eligibility for this study.

Although most respondents were still in the young-elderly group, functional decline was already observed. This was reflected by the high proportion of respondents with very poor lower limb muscle strength and high fall risk. These findings suggest that physical decline in elderly women may begin in the early stage of aging, particularly in components related to muscle strength, mobility, and postural control. Previous studies have shown that aging in women is associated with biological and functional changes that may affect physical performance and increase vulnerability to mobility problems and falls (Hägg & Jylhävä, 2021; Rodrigues et al., 2022). Therefore, fall prevention should not only be focused on very old individuals, but should also begin earlier among young-elderly women.

Relationship Between Lower Limb Muscle Strength and Fall Risk

The findings of this study indicate that lower limb muscle strength is an important factor associated with fall risk among elderly women. Lower limb muscles play a central role in maintaining postural stability, supporting body weight, initiating gait, rising from a sitting position, and producing rapid corrective responses when balance is disturbed. Previous studies have emphasized that lower limb muscle strength is closely related to mobility, postural stability, and fall risk among older adults (Rodrigues et al., 2022; Mustafa et al., 2022).

From a biological perspective, aging is associated with sarcopenia, type II muscle fiber atrophy, reduced motor unit recruitment, and slower neuromuscular activation. In post-menopausal women, reduced estrogen levels may further contribute to decreased muscle mass and strength, thereby worsening postural control (Geraci et al., 2021). These changes reduce the ability of elderly women to generate rapid force needed for balance recovery. This mechanism is supported by Li et al. (2024), who reported that elderly women with a history of falls tend to have lower lower-limb extensor strength and slower neuromuscular activation latency.

Biomechanically, insufficient lower limb muscle strength affects gait stability and weight transfer. Weakness in the quadriceps, hamstrings, gluteal muscles, and ankle stabilizers may reduce the ability to control knee, hip, and ankle movements during walking. As a result, compensatory reactions become slower and less effective, increasing the possibility of imbalance and falls. Similar findings were reported in community-dwelling older adults, where better lower limb muscle strength was associated with lower fall risk (Agustiniari et al., 2025; Mustafa et al., 2022). These findings support the importance of lower limb strengthening exercises as part of fall prevention programs for elderly women.

Relationship Between Kyphosis Degree and Fall Risk

This study also found that kyphosis degree was associated with fall risk. Increased thoracic kyphosis may alter spinal alignment and shift the body's center of gravity anteriorly. This postural change increases the demand on the lower limb and trunk muscles to maintain balance. When compensatory mechanisms are insufficient, postural instability may occur, thereby increasing fall risk. This mechanism is consistent with Niibo et al. (2022), who explained that kyphotic posture can affect postural control strategies, and Koelé et al. (2022), who found that hyperkyphosis was associated with higher fall risk among community-dwelling older adults.

Although most respondents in this study were categorized as having normal posture, kyphosis degree still showed a significant relationship with fall risk. This may be because kyphosis was analyzed not only as a category, but also as a degree of postural change. Therefore, even variations within the normal range may still influence balance control, especially in elderly women

who already have reduced muscle strength. In other words, a respondent does not have to be classified as hyperkyphotic to experience biomechanical changes that may affect stability.

Furthermore, fall risk is influenced by the interaction between posture and physical capacity. A mild increase in thoracic curvature may not directly cause falls when muscle strength and balance responses are adequate. However, when it occurs together with lower limb weakness, reduced neuromuscular response, and age-related physical decline, even smaller postural changes may contribute to impaired balance. Previous research also reported a relationship between thoracic kyphosis degree and postural balance disorders among older adults (Mutnawasitoh et al., 2024). This explains why kyphosis degree remained relevant to fall risk despite the majority of respondents being in the normal posture category.

Combined Contribution of Lower Limb Muscle Strength and Kyphosis Degree to Fall Risk

The regression analysis showed that lower limb muscle strength and kyphosis degree together explained 53.4% of fall risk variation among elderly women. Clinically, this indicates that more than half of the variation in fall risk in this study can be explained by the combined contribution of muscular and postural factors. This finding is important because fall risk is not determined by a single factor, but by the interaction between the ability of the lower limb muscles to stabilize the body and postural alignment that influences balance control.

The combined contribution of these two variables suggests that fall prevention programs should not focus only on strengthening exercises or postural correction separately. Lower limb muscle strengthening is needed to improve stability, gait control, and balance recovery, while postural correction is important to reduce excessive anterior shifting of the center of gravity. Therefore, integrating both approaches may provide a more comprehensive strategy for reducing fall risk among elderly women (Rodrigues et al., 2022; Niibo et al., 2022; Koelé et al., 2022).

However, the remaining 46.6% of fall risk variation was explained by other factors not examined in this study. These factors may include previous fall history, visual impairment, vestibular function, cognitive status, medication use, comorbidities, fear of falling, physical activity level, footwear, and environmental hazards. This is consistent with the concept that fall risk in older adults is multifactorial and may involve intrinsic and extrinsic factors beyond muscle strength and posture (Agustiningrum et al., 2023; Nugraha, 2023). Therefore, although lower limb muscle strength and kyphosis degree are clinically important, fall risk assessment in elderly women should still consider other contributing factors to provide a more complete prevention strategy.

Conclusion

This study found a significant relationship between lower limb muscle strength and fall risk ($r = -0.618$; $p < 0.001$) and between kyphosis degree and fall risk ($r = 0.553$; $p < 0.001$) in elderly women in Pejeng Village. The higher the lower limb muscle strength, the lower the fall risk; conversely, the higher the kyphosis degree, the higher the fall risk. Both variables together explained 53.4% of fall risk variation.

These findings have important clinical implications: physiotherapy interventions incorporating lower limb muscle strengthening and kyphosis postural correction programs should be prioritized in fall prevention programs for elderly women, particularly in rural communities. Healthcare workers and community physiotherapists are encouraged to integrate muscle strength and postural screening into routine elderly examinations as an early detection effort for fall risk.

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