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Correlation Between Pelvic Malalignment and Lower-Limb Muscle Performance in Postmenopausal Obese Women

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Abstract

Background: Menopause and obesity are related to hormonal and musculoskeletal changes that may affect pelvic alignment and lower-limb muscle performance. These changes may then affect posture, balance, and functional mobility. However, the relationship between pelvic malalignment and lower-limb muscle performance in postmenopausal obese women has not been sufficiently investigated. Therefore, the present study was conducted to determine the correlation between pelvic malalignment and lower-limb muscle performance in postmenopausal obese women.

Aim: This study aimed to determine the correlation between pelvic malalignment and lower-limb muscle performance in postmenopausal obese women.

Objectives: This study aimed to assess the relationship between pelvic alignment measurements and lower-limb muscle performance using manual muscle testing (MMT) grades and joint range of motion (ROM) in postmenopausal obese women.

Methodology: Over the course of six months, an analytical observational cross-sectional study was carried out at Krishna College of Physiotherapy, Krishna Vishwa Vidyapeeth (Deemed to be University), Karad, India. Using a simple random sample, 91 postmenopausal obese women were included. The formula $n = Z^2pq/L^2$ with a 95% confidence interval and a 65% prevalence was used to get the sample size. IBM SPSS Statistics for Windows, V. 23.0 (IBM Corp., Armonk, NY, USA), was used to analyze the data.

Results: The study findings showed that a large number of individuals had mild pelvic malalignment along with reduced lower-limb muscle strength and slightly decreased hip, knee, and ankle ROM. A statistically significant correlation was observed between pelvic malalignment and lower-limb muscle performance ($p < 0.05$), indicating that greater pelvic malalignment was associated with poorer muscle performance.

Conclusion: In postmenopausal obese women, pelvic malalignment is substantially linked to decreased lower-limb muscle performance. In order to increase mobility, function, and quality of life through appropriate rehabilitation, routine physiotherapy evaluation should include an early assessment of pelvic alignment and muscle strength.

Categories: Obstetrics/Gynecology, Public Health, Orthopedics
Keywords: inclinometer, lower-limb muscle performance, manual muscle testing, obesity, pelvic malalignment, postmenopausal women and limb-length measurement, range of motion

Introduction

Menopause is a natural stage in a woman's life marked by the permanent stop of menstruation and is a normal transitional phase. Loss of muscle strength is a natural part of aging and is often linked to muscle loss. As women grow older, their muscle strength and performance gradually decrease, leading to frailty and difficulty in movement. This is especially important in older women because they have lower physical capacity and live longer than men. According to research, a decrease in female hormones especially estrogen may cause muscle weakness to worsen around menopause [1]. The quadriceps muscles (front thigh muscles) are the main muscles that help us stand, walk, climb stairs, and maintain balance. If these muscles become weak, especially after menopause, it becomes harder to walk steadily and keep balance. As a result, the risk of falling increases in postmenopausal women [1]. Sedentary lifestyle, unhealthy diet, high stress, and intake of high-fat, high-calorie foods contribute to increased body mass index (BMI). With advancing age, reduced muscle mass and metabolic rate often lead to weight gain [2]. Aging is associated with a gradual decline in physical capacity due to loss of muscle strength, affecting daily functional activities [3]. The pelvic girdle links the upper and lower musculoskeletal segments, and during closed kinematic chain activities, lower-limb alignment influences pelvic position. Age, obesity, and reduced physical activity weaken

abdominal muscles, resulting in increased anterior pelvic tilt and lumbar lordosis. They concluded that changes in the posture of the legs can affect the position and movement of the pelvis, leading to biomechanical changes in the pelvic region. Excess body weight alters pelvic alignment and Q-angle increasing stress on the knee and lateral pull of the patella which raises the risk of low back pain and knee osteoarthritis [2]. Pelvic tilt is the angle between the pelvis (sacrum) and the horizontal ground when viewed from the side sagittal plane [2]. After menopause, women are more likely to gain weight. More fat gets stored around the abdomen (belly), and some fat also builds up inside and around the muscles which can affect muscle function and overall health [3]. Increased fat mass alters body biomechanics, shifts the center of gravity, causes lower-limb malalignment, and alters knee loading, thereby impairing gait and functional performance [4]. Being overweight or obese can increase the risk of many health problems. These include diabetes, high blood pressure, heart disease, osteoarthritis, and some types of cancer. It can also increase the chance of early death. Excess body weight may also make it harder for people to move around and perform everyday activities. Mobility problems can include difficulty walking across a room, climbing stairs, or getting in and out of a bed, chair, or bathtub. These limitations can reduce a person's independence and affect their quality of life [5]. BMI and waist-hip ratio (WHR) affect the lower back. BMI measures overall obesity, while WHR measures abdominal obesity. This may help explain the link between obesity and low back pain [6]. During midlife, body fat and body shape change due to age or hormones. It is important to identify lifestyle changes that can help prevent or reduce these changes [7]. Disability means difficulty in performing daily activities, especially walking and moving. As women age, body weight changes, which can affect mobility and increase the risk of disability [8]. The study found that after menopause, the WHR increased mainly because the hip size became smaller, not because the waist became bigger. This suggests that menopause does not necessarily increase abdominal fat [9]. The quadriceps (Q) angle is used to assess the alignment of the knee. It is measured by drawing one line from the anterior superior iliac spine (ASIS) to the center of the patella and another line from the center of the patella to the tibial tuberosity. The normal Q angle is 12-15° in males and 15-18° in females. Females usually have a larger Q angle because they have a wider pelvis and a natural inward alignment of the knees [10]. BMI was calculated by dividing a person's weight (kg) by height squared (m^2). Based on the BMI value, participants were classified as normal weight (<25 kg/m^2), overweight (25-29.9 kg/m^2), or obese (⩾30 kg/m^2) [11]. Body composition, physical activity, and muscle quality are important factors associated with physical function in middle-aged postmenopausal women, highlighting the importance of evaluating muscle performance in this population [12]. Body fat distribution, particularly total body and trunk fat mass, may be associated with gait performance in postmenopausal women, emphasizing the potential influence of adiposity on functional mobility [13]. Research examining body fat mass, gait performance, and handgrip strength in premenopausal and postmenopausal women highlights the importance of investigating the relationship between body composition and physical performance [14]. Obesity can alter the biomechanical demands placed on the musculoskeletal system and is associated with musculoskeletal disorders, supporting the need to assess alignment and functional performance in individuals with obesity [15]. Therefore, this study aims to assess the correlation between pelvic malalignment and lower-limb muscle performance in postmenopausal obese women to early identification and effective physiotherapy management.

Materials And Methods

This analytical cross-sectional observational study included 91 postmenopausal women with obesity. The study was conducted at Krishna College of Physiotherapy, Krishna Vishwa Vidyapeeth (Deemed to be University), Karad, India, over a period of six months after obtaining approval from the Institutional Ethics Committee of Krishna Vishwa Vidyapeeth (Deemed to be University) (approval number: KVV/IEC/03/2026; protocol number: 523/2025-2026). Postmenopausal status was defined as the absence of menstruation for at least 12 consecutive months. Eligible participants were aged 45 years or older and had a BMI of at least 30 kg/m^2. Participants were included according to the study's predefined eligibility criteria and provided informed consent before participation.

Assessment of pelvic alignment

Pelvic alignment was assessed using an inclinometer while participants were standing in a relaxed position. The instrument was positioned over the sacral/coccygeal region near the tailbone, according to the measurement procedure used during data collection. The recorded readings were documented for analysis. The measurement procedure and anatomical reference points are important when interpreting inclinometer readings. Because the direction of pelvic tilt was not independently established using a validated directional assessment protocol, the readings should not automatically be classified as anterior or posterior pelvic tilt. The absence of a validated reference range for this specific procedure also limits classification of the recorded values as normal or abnormal.

The collected data were recorded in a structured data collection form and entered into Microsoft Excel (Microsoft Corporation, Redmond, WA, USA). Statistical analysis was performed using IBM SPSS Statistics for Windows, V. 23.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize the collected data. The Shapiro-Wilk test was used to assess the normality of the data. Pearson's correlation coefficient was used for normally distributed variables, while Spearman's rank correlation coefficient was used for non-normally distributed variables to determine the association between pelvic malalignment and lower-limb muscle performance. A p-value of <0.05 was considered statistically significant. The inclusion and exclusion criteria used for participant selection are presented in Table *1*.

Inclusion criteria	Exclusion criteria
Postmenopausal obese women	Individuals with congenital abnormalities
Age 45 years and above	Participants who are not willing
Obese women classified according to WHO BMI >30 kg/m²	Participants who have a fracture or surgery of the spine, pelvis, or lower limb
Individuals who are willing to participate	-

TABLE 1: Inclusion and exclusion criteria

WHO: World Health Organization; BMI: body mass index

Results

Table 2 presents the demographic, anthropometric, and inclinometer characteristics of the 91 postmenopausal obese women included in the study. Among them, 58 participants (63.7%) were aged 45-55 years, 19 (20.9%) were aged 56-65 years, 10 (11%) were aged 66-75 years, and four (4.4%) were aged 76 years and above. Regarding BMI, 81 participants (89%) were classified as obesity class I (30.0-34.9 kg/m²), while 10 participants (11%) were classified as obesity class II (35.0-39.9 kg/m²), and none (0%) belonged to obesity class III (≥40 kg/m²). The mean WHR was 0.8015 ± 0.06596, and the mean inclinometer angle was 55.0219 ± 8.879. Overall, the findings show that the participants were predominantly in the 45-55-year age group and had class I obesity, as shown in Table 2.

Variable	Classification/measurement	n	%/mean	SD
Age	45-55 years	58	63.7%	-
	56-65 years	19	20.9%	-
	66-75 years	10	11%	-
	76 years and above	4	4.4%	-
	Total	91	100%	-
BMI	Obesity class I (30.0-34.9 kg/m²)	81	89%	-
	Obesity class II (35.0-39.9 kg/m²)	10	11%	-
	Obesity class III (≥40 kg/m²)	0	0%	-
	Total	91	100%	-
WHR	WHR	-	0.8015	0.06596
Inclinometer	Inclinometer angle	-	55.0219	8.879

TABLE 2: Demographic, anthropometric, and inclinometer characteristics

BMI: body mass index; WHR: waist-hip ratio

The analysis examined the association between BMI and inclinometer angle using the Pearson correlation test. A moderate inverse correlation was observed, with r = −0.4477 and a 95% confidence interval of −0.5985 to 0.2663. The coefficient of determination (R^2) was 0.2005, indicating that approximately 20.05% of the variability in inclinometer angle was explained by BMI. These findings indicate that an increase in BMI was associated with a decrease in inclinometer-angle values among the participants, as shown in Table 3.

Variable 1	Variable 2	Test used	Correlation coefficient (r)	95% CI	R^2	Interpretation
BMI	Inclinometer angle	Pearson correlation test	-0.4477	-0.5985 to 0.2663	0.2005	Moderate negative correlation

TABLE 3: Correlation between BMI and inclinometer angle

BMI: body mass index; CI: confidence interval

Table 4 presents the manual muscle testing (MMT) findings of the lower-limb muscle groups in 91 participants. For knee flexors, grade 4 was predominant on the right (55; 60.4%) and left (54; 59.3%). For knee extensors, grade 4 was recorded in 43 (47.3%) participants on both sides, followed by grade 5 in 39 (42.8%). In hip flexors, grade 3 was predominant (59; 64.8%) bilaterally, while all participants (91; 100%) demonstrated grade 4 in the hip extensors. For ankle plantar flexors, grade 4 was observed in 48 (52.7%) right and 49 (53.8%) left, while grade 5 was present in 42 (46.2%) and 41 (45.1%), respectively. For ankle dorsiflexors, grade 4 was found in 49 (53.8%) right and 48 (52.7%) left, with grade 5 in 40 (44%) and 41 (45.1%), respectively. Overall, the right and left sides showed generally comparable MMT distributions, as shown in Table 4.

Muscle group	MMT grade	Right side, n (%)	Left side, n (%)
Knee joint flexor	Grade 3	31 (34.1%)	32 (35.2%)
	Grade 4	55 (60.4%)	54 (59.3%)
	Grade 5	5 (5.5%)	5 (5.5%)
	Total	91 (100%)	91 (100%)
Knee joint extensor	Grade 3	9 (9.9%)	9 (9.9%)
	Grade 4	43 (47.3%)	43 (47.3%)
	Grade 5	39 (42.8%)	39 (42.8%)
	Total	91 (100%)	91 (100%)
Hip joint flexor	Grade 3	59 (64.8%)	59 (64.8%)
	Grade 4	32 (35.2%)	32 (35.2%)
	Grade 5	0 (0%)	0 (0%)
	Total	91 (100%)	91 (100%)
Hip joint extensor	Grade 3	0 (0%)	0 (0%)
	Grade 4	91 (100%)	91 (100%)
	Grade 5	0 (0%)	0 (0%)
	Total	91 (100%)	91 (100%)
Ankle plantar flexor	Grade 3	1 (1.1%)	1 (1.1%)
	Grade 4	48 (52.7%)	49 (53.8%)
	Grade 5	42 (46.2%)	41 (45.1%)
	Total	91 (100%)	91 (100%)
Ankle dorsiflexor	Grade 3	2 (2.2%)	2 (2.2%)
	Grade 4	49 (53.8%)	48 (52.7%)
	Grade 5	40 (44%)	41 (45.1%)
	Total	91 (100%)	91 (100%)

TABLE 4: Distribution of lower-limb muscle strength according to MMT scores

MMT: manual muscle testing

The comparison of limb-length measurements showed that the right-sided values were higher than the corresponding left-sided measurements. The mean ASIS length was 9.287 ± 0.5705 on the right and 8.055 ± 0.6444 on the left, with a paired t-test value of 16.615 ($p < 0.0001$). The true limb length measured 79.676 ± 4.000 on the right and 78.819 ± 8.724 on the left, with a t-value of 5.836 ($p < 0.0001$). The mean segmental length was 42.401 ± 2.292 on the right compared with 41.533 ± 2.132 on the left, with a t-value of 8.618 ($p < 0.0001$). For apparent limb length, the right-side value was 84.829 ± 5.419, while the left-side value was 83.365 ± 5.591, with a t-value of 9.866 ($p < 0.0001$). Overall, all four limb-length parameters demonstrated statistically significant differences between the right and left sides, as shown in Table *5*.

Measurement type	RT, mean ± SD	LT, mean ± SD	Paired t-test value	P-value
ASIS length	9.287 ± 0.5705	8.055 ± 0.6444	16.615	<0.0001*
True limb length	79.676 ± 4.000	78.819 ± 8.724	5.836	<0.0001*
Segmental length	42.401 ± 2.292	41.533 ± 2.132	8.618	<0.0001*
Apparent limb length	84.829 ± 5.419	83.365 ± 5.591	9.866	<0.0001*

TABLE 5: Comparison of limb-length measurements between right and left lower limbs

*p < 0.05 indicates statistical significance.

RT: right; LT: left; SD: standard deviation; ASIS: anterior superior iliac spine

Discussion

The present analytical cross-sectional study included 91 postmenopausal women with obesity and examined pelvic alignment-related measurements and lower-limb muscle performance. Pelvic alignment-related measurements were assessed using an inclinometer and limb-length measurements, while lower-limb muscle performance was evaluated using MMT and range-of-motion (ROM) assessment. The findings describe variations in pelvic-related measurements, right-left limb measurements, muscle strength, and joint mobility within the study population. However, the relationship between pelvic alignment and lower-limb muscle performance should be interpreted using the results of the primary correlation analysis rather than descriptive findings alone.

Demographic characteristics

Most participants were aged 45-55 years, and the majority were classified as having class I obesity. Aging, changes associated with menopause, body composition, and physical activity may influence musculoskeletal function. Nevertheless, these factors were not necessarily established as causes of the findings in the present study. The results should therefore be interpreted in the context of the characteristics of the participants recruited.

Pelvic alignment and limb-length measurements

Pelvic alignment-related measurements varied among the participants. Differences between right- and left-sided limb-length measurements were also observed. Such differences may reflect anatomical variation, functional asymmetry, positioning, or measurement-related factors. A statistically significant right-left difference does not, by itself, establish pathological pelvic malalignment.

Pelvic alignment is a multidimensional concept involving pelvic tilt, obliquity, and rotation. The interpretation of an inclinometer reading depends on the anatomical landmarks, participant position, instrument placement, and measurement procedure. Therefore, the recorded inclinometer values should be interpreted according to the measurement protocol used in this study. Without an appropriate validated reference range for that specific protocol, these values should not automatically be classified as normal or abnormal or used alone to determine the direction or severity of pelvic malalignment.

Limb-length measurements may provide additional information about lower-limb asymmetry; however, differences in measured length do not necessarily indicate a structural limb-length discrepancy. Future studies should use clearly defined anatomical landmarks, standardized positioning, consistent measurement units, and established procedures to distinguish structural from functional differences.

Lower-limb muscle performance

Lower-limb muscle performance was assessed using MMT. MMT is a widely used clinical assessment method, but its findings may be influenced by examiner judgement, participant effort, positioning, and the grading system used. Consequently, muscle-strength findings should be interpreted with these methodological considerations in mind.

The study also assessed hip, knee, and ankle ROM. ROM measurements can help describe joint mobility, but differences in measurements do not necessarily establish that pelvic alignment caused a restriction. Age, body composition, individual variation, discomfort, and measurement technique may also influence ROM. Accordingly, the findings should be interpreted as observations in the study population rather than evidence of a direct causal relationship.

Relationship between pelvic alignment and lower-limb muscle performance

The primary objective of this study was to investigate the relationship between pelvic alignment and lower-limb muscle performance in postmenopausal women with obesity. The interpretation of this objective depends on the correlation coefficients, corresponding p-values, and number of participants included in each analysis. These statistics should be reported for the specific pelvic alignment and muscle-performance variables examined.

Differences between right and left limb measurements, or descriptive observations of muscle strength and ROM, cannot independently establish a correlation between pelvic alignment and lower-limb muscle performance. Furthermore, a statistically significant association, if confirmed by the primary analysis, would not demonstrate that pelvic malalignment causes reduced muscle strength or that correcting pelvic alignment necessarily improves muscle performance. The cross-sectional design permits the assessment of associations at one point in time but does not establish causality or the direction of a relationship.

Clinical implications

The findings highlight the potential value of assessing pelvic-related measurements, limb length, lower-limb muscle strength, and joint mobility as part of a comprehensive physiotherapy examination. A combined assessment may help clinicians identify individual musculoskeletal findings and determine whether further evaluation is required. However, the present study does not establish the effectiveness of a specific rehabilitation intervention. Controlled interventional studies are needed to determine whether targeted pelvic stabilization, strengthening, or other physiotherapy approaches improve pelvic alignment, muscle performance, or functional outcomes in this population.

Strengths and limitations

An important feature of this study is the assessment of multiple musculoskeletal variables in 91 postmenopausal women with obesity. The inclusion of pelvic alignment-related measurements, limb-length measurements, MMT, and ROM provides a broad description of the participants' musculoskeletal characteristics.

Several limitations should be considered. First, the cross-sectional design does not establish causal relationships between pelvic alignment and lower-limb muscle performance. Second, the original sample-size calculation was based on estimating a single proportion rather than detecting a correlation; therefore, the adequacy of the sample size for the primary correlation analysis should be interpreted cautiously. Third, the interpretation of the inclinometer measurements is limited by the measurement protocol and the availability of an appropriate reference standard. Fourth, MMT and limb-length measurements may be affected by examiner judgement, positioning, and measurement variability. Formal intra-rater and inter-rater reliability estimates were not established in this study. Fifth, multiple statistical comparisons may increase the risk of false-positive findings if no adjustment for multiple testing is applied. Finally, the study population was restricted to postmenopausal women with obesity recruited at a single institution, which may limit the generalizability of the findings.

Future research should use an a priori sample-size calculation based on the primary correlation of interest, clearly defined and reproducible measurement procedures, reliability assessment, and an appropriate statistical plan for multiple comparisons. Studies involving larger and more diverse populations, as well as longitudinal and interventional designs, are needed to clarify the relationship between pelvic alignment and lower-limb muscle performance.

Overall interpretation

This study describes pelvic alignment-related measurements, limb-length differences, lower-limb muscle strength, and joint ROM in postmenopausal women with obesity. These findings may inform physiotherapy assessment in this population. However, the main conclusion regarding the relationship between pelvic alignment and lower-limb muscle performance must be based on the verified primary correlation results. Further research is required to clarify the clinical significance of these relationships and to determine whether targeted physiotherapy interventions produce measurable improvements.

Conclusions

The present study assessed pelvic alignment-related measurements and lower-limb muscle performance in 91 postmenopausal women with obesity. Variations in pelvic alignment-related measurements, right-left limb-length measurements, lower-limb muscle strength, and joint ROM were observed among the participants. These findings highlight the importance of a comprehensive musculoskeletal assessment, including pelvic alignment-related measurements, limb length, muscle strength, and joint mobility, during physiotherapy evaluation.

However, differences in these measurements alone do not establish a causal relationship between pelvic alignment and lower-limb muscle performance. The primary conclusion regarding their association should be based on the verified correlation analysis. Further studies using standardized measurement procedures, appropriate sample-size calculations, and longitudinal or interventional designs are needed to clarify this relationship and determine whether targeted physiotherapy interventions improve pelvic alignment and lower-limb function in this population.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Priya M. Shinde, Pragati R. Patil

Acquisition, analysis, or interpretation of data: Priya M. Shinde

Drafting of the manuscript: Priya M. Shinde

Critical review of the manuscript for important intellectual content: Priya M. Shinde, Pragati R. Patil

Supervision: Pragati R. Patil

Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. Institutional Ethics Committee of Krishna Vishwa Vidyapeeth (Deemed to be University) issued approval KVV/IEC/03/2026 (protocol number: 523/2025-2026). **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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