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Original Research

Muscle Weakness, Proprioceptive Deficits, and Postural Stability in Unilateral Knee Osteoarthritis: A Comparative Analysis of Affected and Unaffected Limbs

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Abstract

Objective: This study aimed to investigate quadriceps and hamstring muscle strength, postural stability, proprioceptive sense, and weight-bearing asymmetry between the affected and unaffected lower limbs in patients with unilateral knee osteoarthritis (OA).
Materials and Methods: A total of 79 patients (70 women, nine men; mean age 61.08 ± 6.28 years) diagnosed with unilateral knee OA according to the Kellgren-Lawrence classification were included. Demographic and clinical characteristics were recorded. Pain intensity was assessed using the Visual Analog Scale, and functional status was evaluated with the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). Muscle strength was measured with a manual muscle dynamometer, proprioception with joint position sense tests at different knee flexion angles, and postural stability using a force platform under both eyes-open and eyes-closed conditions. Weight-bearing distribution during bilateral stance was also evaluated.
Results: Quadriceps and hamstring strength were significantly lower in the affected limb compared to the unaffected side ($p \leq 0.001$). Weight-bearing on the affected limb was reduced under both eyes-open and eyes-closed conditions ($p \leq 0.001$). However, no significant interlimb differences were observed in postural stability parameters or proprioceptive accuracy at any tested angles ($p > 0.05$). Additionally, patients demonstrated a significant asymmetry in load transfer during bilateral stance, favoring the non-affected limb.
Conclusion: Patients with unilateral knee OA exhibit reduced muscle strength and weight-bearing capacity in the affected limb, along with asymmetrical load distribution during stance. These findings highlight the importance of addressing weight-bearing asymmetry and muscle weakness in early rehabilitation programs to prevent further functional deterioration and disease progression.

Keywords: *knee, osteoarthritis, postural balance, proprioception*

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Introduction

Osteoarthritis (OA) is the most common joint disorder worldwide, affecting an estimated 240 million people and leading to significant functional limitations in the adult population, particularly in activities such as walking and stair climbing (Katz et al., 2021). Knee OA is the most prevalent form of OA, with high morbidity and disability rates (Geng et al., 2023). The main clinical features of the disease include progressive degeneration of the articular cartilage, structural changes in the subchondral bone, joint space narrowing, pain, and functional impairment. The negative effects of knee OA on lower extremity function, ambulation, and activities of daily living lead to decreased independence at the individual level and impose a substantial health burden at the societal level (Katz et al., 2021; Schepman et al., 2022). The pathophysiology of OA is not limited to degenerative processes in the articular cartilage; it also involves muscle weakness, proprioceptive deficits, impairments in postural control, and asymmetries in weight-bearing, all of which are important contributors to the clinical picture (Bakırhan et al., 2013; Labanca et al., 2021). In particular, quadriceps muscle weakness has been identified as a critical risk factor for both the onset and progression of knee OA (Al-Johani et al., 2014). In addition to quadriceps weakness, reductions in hamstring strength also play a key role in pain, functional capacity, and joint stability (Lopes et al., 2024).

Proprioception plays a vital role in the perception of joint motion and the maintenance of joint stability. Consequently, proprioceptive deficits are inevitably associated with impairments in postural stability (Labanca et al., 2021; Mani et al., 2020). Proprioceptive input is essential for sustaining functional tasks, particularly during daily activities such as walking and stair climbing (Riva et al., 2013). In the literature, proprioception in individuals with knee OA is most commonly assessed through measures of joint position sense error, and studies have reported that proprioceptive deficits may occur not only in the affected limb but also in the contralateral, asymptomatic side (Gokeler et al., 2012; Sharma, 1999).

Postural stability is of critical importance for balance performance and fall prevention. In individuals with knee OA, proprioceptive deficits combined with age-related declines in motor control adversely affect postural stability and increase the risk of falls (Labanca et al., 2021; Zeng et al., 2022). Impairments in postural stability, manifested as deficits in standing balance and asymmetries in weight-bearing, are frequently observed in both unilateral and bilateral knee OA. Such impairments may exacerbate functional limitations by elevating fall risk. Weight-bearing asymmetry is also clinically relevant, as it may influence disease progression and functional outcomes (Ashraf et al., 2011; Nishizawa et al., 2021).

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Although studies investigating muscle strength, proprioception, postural stability, and weight-bearing asymmetry in patients with knee OA exist, many have been limited by small sample sizes or rely primarily on comparisons with healthy controls. Research comparing both extremities in terms of muscle strength and proprioception has reported that deficits may also occur in the contralateral, ostensibly unaffected limb. However, studies examining postural stability and weight-bearing asymmetry remain insufficient. In particular, impairments in the unaffected limb of individuals with unilateral knee OA should not be overlooked and should be incorporated into the rehabilitation process.

The primary hypothesis of this study was that differences in quadriceps muscle strength exist between the affected and unaffected sides in individuals with unilateral knee OA. Our secondary hypothesis was that individuals with unilateral knee osteoarthritis would exhibit increased proprioceptive error and reduced load transfer on the affected side.

Materials and Methods

Study Design

This study was designed as an observational, cross-sectional study. It was conducted between November 2024 and May 2025 at the Hacettepe University. Ethical approval was obtained from the Institutional Review Board of the investigators' affiliated institution (Approval date: 06.02.2024; Approval number: SBA 24/220). The procedures of the study were carried out in accordance with the principles of the Declaration of Helsinki. All participants were informed about the study and provided written informed consent prior to participation.

Participants

Seventy-nine patients diagnosed with unilateral knee osteoarthritis (OA) were included. Inclusion criteria were: being between 45 and 70 years of age and having a diagnosis of unilateral knee OA, classified as grade 2–4 according to the Kellgren-Lawrence radiographic OA classification. Exclusion criteria were: limitation of knee range of motion; history of neurological, rheumatological, oncological, vestibular, or cognitive disorders; history of lower extremity surgery or injury; having received intra-articular injection for knee OA in the last 6 months; participation in a physiotherapy program within the last 6 months; pregnancy or childbirth within the last year (for female participants).

The required sample size was determined using G*Power 3.1.9.2 software. Based on the effect size (0.426) calculated from quadriceps muscle strength measurements of the affected

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and unaffected sides in unilateral knee OA patients, as reported by Hislop et al. (2022) and considering a 5% alpha level with 95% power, a minimum of 74 participants was deemed sufficient. To account for potential missing data, 79 participants were ultimately included.

Assessment Tools

Demographic and Clinical Data

Age, height, body weight, and body mass index (BMI) of the participants were recorded. In addition, the dominant side and the affected side were identified and documented. To determine the participants' dominant lower limb, they were asked, "If a ball were coming toward you, which foot would you use to kick it?" The limb they selected was recorded as their dominant lower extremity.

Pain Assessment

Current knee pain severity was assessed using the Visual Analog Scale (VAS). Participants were asked to indicate their pain intensity on a 10-cm horizontal line, which was later measured in centimeters. A score of 0 represented "no pain," while a score of 10 represented "worst imaginable pain". VAS is a widely used valid and reliable tool for pain assessment in knee OA (Alghadir et al., 2018).

Muscle Strength Assessment

Quadriceps and hamstring muscle strength were assessed using a handheld dynamometer (KINVENT K-Force, Orsay, France) (de Almeida et al., 2023). Data were collected via the KINVENT PHYSIO application through Bluetooth connection. Isometric muscle strength was evaluated following the device's standardized protocol.

Hamstring strength was assessed with the patient in the prone position, hips in 0° extension, and knees flexed to 90°. The dynamometer was placed approximately 5 cm above the ankle joint, and participants were instructed to pull their heel toward the hip as forcefully as possible, while the examiner applied counterforce to prevent movement (de Almeida et al., 2023). Quadriceps strength was assessed in a seated position with hips and knees flexed at 90°. The device was placed 5 cm above the ankle joint anteriorly, and participants were instructed to extend the knee as forcefully as possible, while the examiner applied counterforce.

Contraction duration was standardized to 5 seconds, with a 10-second rest between trials. Participants performed a practice trial before testing. Each muscle group was tested three times, and the best value was recorded. Force data were normalized to body weight (N/kg) for analysis.

Knee Joint Proprioception

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Knee joint proprioception was assessed using joint position sense (JPS) measurements with a digital goniometer (KINVENT K-Move, Orsay, France). Data were recorded digitally through the KINVENT PHYSIO application. The goniometer was secured to the distal part of the knee joint using Velcro straps (Eymir et al., 2021). Participants were seated with hips and knees at 90° flexion. JPS was tested at 30°, 45°, and 60° knee flexion. The procedure consisted of three steps: From 0° extension, the examiner passively moved the knee to the target angle and asked the participant to hold the position for 3 seconds with eyes open. After this learning phase, the participant actively reproduced the target angle from 0° extension with eyes closed. Upon perceiving the target angle, participants held the position for 3 seconds and verbally indicated completion. Three trials were performed for each angle after three learning attempts. A 5-minute rest period was given between different angle assessments. Errors between the target and reproduced angles were digitally recorded.

Postural Stability

Postural stability was evaluated using K-PLATES (Kinvent, Montpellier, France), consisting of two pressure-sensitive platforms (320 × 160 mm). The system measured the center of pressure (COP) sway area (mm²), anteroposterior (AP) sway distance (mm), mediolateral (ML) sway distance (mm), and weight-bearing distribution between sides (Sørensen et al., 2014).

Measurements were performed in quiet standing with eyes open and eyes closed. The device was calibrated before each assessment. Participants stood barefoot, with feet placed on the respective platforms and arms relaxed at the sides. Each trial lasted 30 seconds, preceded by a 5-second preparation period. Two trials (eyes open and eyes closed) were recorded for each participant. Data were transferred via Bluetooth to the KINVENT PHYSIO application (Meras Serrano et al., 2023).

Knee-Related Function

Knee-related function was assessed using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). This validated and reliable questionnaire in Turkish consists of 24 items divided into three subscales: pain (5 items), stiffness (2 items), and physical function (17 items). Each item is scored on a 5-point Likert scale (0 = none, 4 = extreme). Maximum possible scores are 20 for pain, 8 for stiffness, 68 for function, and 96 in total. Higher scores indicate greater symptom severity and disability (Tüzün et al., 2005).

Statistical Analysis

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Statistical analyses were conducted using SPSS software (version 27.0, IBM Corp., Armonk, NY, USA). Data distribution was assessed using the Kolmogorov-Smirnov test. Demographic and clinical data were expressed as mean ± standard deviation (mean ± SD). Since the data were not normally distributed, comparisons between affected and unaffected limbs in terms of muscle strength, weight-bearing, proprioception, and postural sway parameters were performed using the Wilcoxon Signed-Rank Test. The level of significance was set at $p < 0.05$.

Results

A total of 79 patients with unilateral knee osteoarthritis (OA) were included in the study. The mean age of the participants was 61.08 ± 6.28 years; 70 were women (88.6%), and 9 were men (11.6%). The mean height was 159.61 ± 6.39 cm, the mean body weight was 76.82 ± 10.3 kg, and the mean body mass index (BMI) was 30.17 ± 3.71 kg/m². According to the Kellgren-Lawrence OA classification, 32 patients (36.7%) were classified as grade II, 25 patients (35.4%) as grade III, and 22 patients (27.8%) as grade IV. The right knee was affected in 60.8% of the patients, and 93.7% had right-side dominance. The demographic characteristics of the patients are presented in Table 1.

Table 1. Demographic and Clinical Characteristics of the Participants

N=79	**X±SD**
Age (year)	61.08±6.28
Height (cm)	159.61±6.39
Weight (kg)	76.82±10.3
BMI (kg/cm2)	30.17±3.71
Gender	N (%)
Female	70 (88.6)
Male	9 (11.4)
Affected Extremity	N (%)
Right	48 (60.8)
Left	31 (39.2)
Dominant Lower Extremity	N (%)
Right	74 (93.7)
Left	5 (6.3)
Kellgren-Lawrence OA Stage	N (%)
Stage II	32 (36.7)
Stage III	25 (35.4)
Stage IV	22 (27.8)
Pain (cm)	5.36±2.58
WOMAC-pain	8.01±3.88
WOMAC-Stiffness	1.18±1.71
WOMAC-Function	24.76±13.05
WOMAC Total	35.03±16.73

Abbreviations: X ± SD: Mean ± Standard Deviation; BMI: Body Mass Index; OA: Osteoarthritis; WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index.

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The clinical assessment results of the patients are presented in Table 1. The mean knee pain score was 5.36 ± 2.59. In the WOMAC questionnaire, the mean pain score was 8.01 ± 3.88 points, stiffness score 1.18 ± 1.71 points, and function score 24.76 ± 13.05 points. The mean total WOMAC score was 35.03 ± 16.73 points.

Table 2. Comparison of Outcome Measures Between the Affected and Unaffected Sides

Outcomes N=79			**Affected side** X±SD	**Unaffected side** X±SD	***p***
Muscle strength		Quadriseps (N/kg)	2.37±1.07	2.64±1.16	≤ **0.001**
		Hamstring kas (N/kg)	0.86±0.44	0.95±0.47	≤ **0.001**
Weight-bearing distribution		Eyes-opened (%)	46.88±5.90	53.10± 5.89	≤ **0.001**
		Eyes-closed (%)	47.08±5.42	52.92± 5.41	≤ **0.001**
Joint position sense		0°- 30°	5.31±3.31	4.70±4.32	0.138
		0°- 45°	5.97±4.19	4.98±4.11	0.160
		0°- 60°	5.31±4.33	4.97±4.11	0.471
Postural stability	**Eyes-opened**	AP Sway distance (mm)	272.53±82.54	286.26 ±94.55	0.253
		ML Sway distance (mm)	80.11±29.17	82.83±30.97	0.290
		COP Sway area (mm^2)	41.93±33.41	43.46± 41.06	0.970
	Eyes-closed	AP salınım mesafesi (mm)	329.72±124.68	342.06±133.51	0.262
		ML salınım mesafesi (mm)	92.46±38.47	95.85± 42.18	0.201
		COP Sway area (mm^2)	46.87±41.69	51.03±59.29	0.827
	Eyes-opened (Total)	AP Sway distance (mm)	256.12 ±73.05		
		ML Sway distance (mm)	146.54±48.36		
		COP Sway area (mm^2)	286.59±173.16		
	Eyes-closed (Total)	AP Sway distance (mm)	315.17±113.18		
		ML Sway distance (mm)	158.38±64.66		
		COP Sway area (mm^2)	326.17±291.65		

Abbreviations: X ± SD: Mean ± Standard Deviation; AP, Anteroposterior; ML, Mediolateral; COP, Center of Pressure.

The comparisons of muscle strength, postural stability parameters, knee proprioception, and weight-bearing between the affected and unaffected lower extremities are presented in

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Table 2. In terms of muscle strength, both quadriceps and hamstring strength were found to be significantly lower in the affected limb ($p \leq 0.001$). Weight-bearing on the affected side was also significantly reduced under both eyes-open and eyes-closed conditions ($p \leq 0.001$). However, postural stability parameters in both eyes-open and eyes-closed conditions, as well as knee proprioception at all tested angles, were similar between the two sides ($p > 0.05$).

Discussion and Conclusion

The aim of this study was to compare postural stability, weight distribution, muscle strength, and joint position sense between the affected and unaffected knees in patients with unilateral knee osteoarthritis (OA). The results demonstrated that quadriceps and hamstring muscle strength, as well as weight-bearing on the affected limb, were significantly lower compared to the unaffected limb. However, joint position sense across all tested angles and postural stability parameters were similar between the two sides. Another notable finding was that, despite increased knee pain, the functional status of the patients had not deteriorated substantially.

The mean pain level of participants was 5.36 on the Visual Analog Scale (VAS). Knee pain associated with OA has been well-documented in the literature, and VAS is a widely accepted and reliable method for its assessment (Alghadir et al., 2018). Patients across radiological OA stages II, III, and IV were included. Typically, patients with knee OA seek medical attention due to pain during activity and subsequent difficulty in daily life activities (Duong et al., 2023), which may explain the moderate-to-high mean pain scores in our cohort. The mean WOMAC scores were 8.01/20 for pain, 1.81/8 for stiffness, 24.76/64 for function, and 35.03/96 for the total score. While pain scores were above average, the other subscales and total score were lower than the midpoint, suggesting that functional impairment was less severe. WOMAC is a frequently used, valid, and reliable tool for assessing functional status in knee OA (Roos, 1999; Samuel & Kanimozhi, 2019). Onodera et al. (2020) reported higher WOMAC scores in a study including patients with OA stages II-IV, possibly due to the inclusion of both unilateral and bilateral cases. Conversely, Scopaz et al. (2009) reported lower WOMAC scores, though the affected limb was not specified.

Muscle Strength

Consistent with previous studies (Ishii et al., 2020; Marks, 2016), our results indicated a significant reduction in muscle strength around the affected knee. Quadriceps weakness is attributed to disuse atrophy from pain, impaired neuromuscular activation patterns, and

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inflammatory processes (Dalle & Koppo, 2020; Ikemoto-Uezumi et al., 2017). Furthermore, quadriceps weakness is recognized as a critical risk factor for both the development and progression of knee OA (Segal & Glass, 2011). Al-Johani et al. reported that hamstring strength, alongside quadriceps strength, is important for pain management and knee function in OA (Al-Johani et al., 2014). Recent meta-analyses also support the association between knee OA and hamstring weakness (Lopes et al., 2024). Our findings align with the literature, showing significant decreases in both quadriceps and hamstring strength in the affected limb. Weakness in periarticular muscles of the knee is a key risk factor for functional deficits, postural instability, and fall risk (Kim et al., 2018; Manlapaz et al., 2019; Zeng et al., 2022). These results highlight the importance of including both quadriceps and hamstrings in OA rehabilitation programs.

Postural Stability and Weight Distribution

Postural stability is crucial for balance maintenance and fall prevention, and knee OA negatively affects it (Chen et al., 2020; Goble & Baweja, 2018; Labanca et al., 2021). Although postural stability parameters were similar between affected and unaffected limbs in our study, overall values exceeded normative ranges for healthy adults aged 45–65 (Goble & Baweja, 2018). Large-scale studies using similar assessment tools have reported age-related increases in postural sway, particularly in men. This supports the notion that both proprioceptive deficits and age-related postural control impairments negatively influence balance in OA patients. Zeng et al. (2022) reported that individuals with knee OA had increased center-of-pressure (COP) sway compared to healthy controls, indicating reduced postural stability. While various devices and protocols in the literature complicate direct comparisons, the general consensus indicates impaired postural stability in knee OA (Lawson et al., 2015). Sway area is an important indicator and is frequently used (Chen et al., 2020; Takacs et al., 2014). In our study, despite no differences between limbs, total COP sway under eyes-open and eyes-closed conditions exceeded reference values (women: 134±99.2 mm^2, men: 191±121 mm^2), indicating impaired postural stability. Increased sway is critical as it elevates fall risk.

Another finding of our study was the presence of a significant asymmetry in weight distribution between the lower extremities during bilateral stance. Patients with unilateral knee OA were found to shift a greater proportion of their body weight onto the unaffected limb. This difference was significant under both eyes-open and eyes-closed conditions. In individuals with unilateral or bilateral knee OA, asymmetrical weight-bearing may occur due to various clinical and biomechanical reasons (Nagymate & Kiss, 2017; Nagymate et al., 2016; Nishizawa et al.,

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2021). Consistent with our results, Bakırhan et al. reported that patients with unilateral knee OA transferred more load to the non-affected limb, particularly during standing and activities requiring knee flexion (Bakırhan et al., 2013). Such asymmetrical weight distribution in patients with knee OA may negatively affect bone mineral density and contribute to the progression of OA (Ashraf et al., 2011; Nishizawa et al., 2021). In our study, among the patients, 74% were right dominant, whereas 48% had the right lower limb as the affected extremity. The difference between these proportions suggested that the observed variation in weight distribution was unlikely to be influenced by lower limb dominance. Moreover, there is no clear consensus in the literature regarding the relationship between lower limb dominance and load transfer between extremities (Paillard & Noé, 2020). Therefore, it should be addressed in rehabilitation programs starting from the early stages.

Proprioception

Proprioception plays a critical role in protecting the knee during daily activities and preventing falls, yet it is often impaired in knee OA (Knoop et al., 2011; Labanca et al., 2021; Mani et al., 2020). Literature suggests that unilateral knee OA may also compromise proprioception in the contralateral limb (Knoop et al., 2011; Sharma, 1999), possibly due to reduced mechanoreceptor function in the affected knee or compensatory overuse of the unaffected side (Sharma, 1999; Zeng et al., 2022). In our study, joint position sense errors at 30°, 45°, and 60° were similar between affected and unaffected knees, indicating bilateral proprioceptive deficits. This underscores the importance of including both limbs in rehabilitation programs. The clinical significance of specific joint position errors remains unclear; studies suggest that errors >5° may be meaningful (Baert et al., 2018) though smaller deviations could also impact the function (Lee et al., 2021). In our study, mean errors were 5.53° for the affected knee and 4.88° for the unaffected knee, supporting the concept of bilateral impairment in unilateral OA.

The findings indicate that in individuals with unilateral knee OA, muscle strength in the affected limb is significantly reduced, and weight-bearing is limited. Although postural stability parameters measured during bilateral stance did not differ between limbs, overall postural stability was substantially impaired relative to reference values. Similar postural stability and joint position sense across both limbs suggest bilateral involvement. Rehabilitation should integrate muscle strengthening, weight-bearing training, and balance exercises to optimize functional recovery. Clinicians should consider both symptomatic and asymptomatic limbs when planning interventions.

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Study Limitations

Several limitations should be noted. First, knee proprioception was assessed only via joint position sense, excluding other sensory modalities such as kinesthesia. Second, factors such as physical activity level, duration of pain, and analgesic use were not evaluated or controlled. Another limitation of the study was that, since knee osteoarthritis is more prevalent in women, the number of female participants was considerably higher than that of male participants. The cross-sectional design precludes causal inferences. Finally, the inclusion of patients across three OA stages limited the ability to analyze stage-specific differences. Future studies are needed that include a more balanced ratio of male and female participants and incorporate a control group for comparison.

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Declaration of Competing Interest

The authors declare that there is no conflict of interest regarding any institution, organization, or among the researchers within the scope of this study.

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