ARAŞTIRMA MAKALESİ / *RESEARCH ARTICLE*

The Relationship Between Knee Osteoarthritis Severity, Muscle Strength, Proprioception, and Quality of Life

Diz Osteoartriti Şiddeti, Kas Kuvveti, Propriyosepsiyon ve Yaşam Kalitesi Arasındaki İlişki

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ABSTRACT

Aim: *This study investigated the relationship between the severity of knee osteoarthritis (OA) and key clinical factors such as muscle strength, proprioception, and quality of life (QoL) in individuals with bilateral knee OA.*

Material and Methods: *A cross-sectional observational study was conducted with 40 participants diagnosed with bilateral knee OA. Isometric quadriceps and hamstring muscle strength were measured using a hand-held dynamometer. Proprioception was assessed using a digital inclinometer during knee flexion at 30° and 60°. Osteoarthritis severity was determined using the Kellgren-Lawrence classification and the Lequesne Algofunctional Knee Index, while QoL and functional status were evaluated using the WOMAC Index.*

Results: *As OA severity increased, significant increases were observed in WOMAC pain, stiffness, and physical function scores, indicating worse outcomes in QoL ($p<0.05$). Proprioception was notably impaired at 60° of knee flexion in the non-dominant leg as OA grade increased. At the same time, no significant muscle strength decline in the quadriceps and hamstrings was observed across OA grades ($p>0.05$).*

Conclusions: *OA severity is closely associated with worse QoL outcomes, particularly in pain and physical function, but not consistently with muscle strength. These findings highlight the need for rehabilitation programs that improve proprioception and pain management in OA patients.*

Key words: *osteoarthritis severity; osteoarthritis grade; knee proprioception; life quality; WOMAC; knee muscle strength*

ÖZET

Amaç: *Bu çalışma, bilateral diz osteoartriti (OA) olan bireylerde diz OA şiddeti ile kas kuvveti, propriyosepsiyon ve yaşam kalitesi gibi temel klinik faktörler arasındaki ilişkiyi araştırmayı amaçlamıştır.*

Gereç ve Yöntem: *Bilateral diz OA tanısı konan 40 katılımcı ile kesitsel bir gözlemsel çalışma yapılmıştır. İzometrik kuadriseps ve hamstring kas kuvveti, elle tutulan bir dinamometre kullanılarak ölçüldü. Propriyosepsiyon, 30° ve 60°'de diz fleksiyonu sırasında dijital bir inklinometre kullanılarak değerlendirildi. Osteoartrit şiddeti, Kellgren-Lawrence sınıflandırması ve Lequesne algofonksiyonel diz indeksi kullanılarak belirlenirken, yaşam kalitesi ve fonksiyonel durum WOMAC endeksi kullanılarak değerlendirildi.*

Bulgular: *OA şiddeti arttıkça, WOMAC ağrısı, sertlik ve fiziksel fonksiyon skorlarında anlamlı artışlar gözlenmiştir, bu da yaşam kalitesinde daha kötü sonuçları gösterir ($p <0,05$). Propriyosepsiyon, OA derecesi arttıkça dominant olmayan bacaktaki 60° diz fleksiyonunda önemli ölçüde bozuldu. Aynı zamanda, OA derecelerinde kuadriseps ve hamstringlerde belirgin bir azalma gözlenmemiştir. ($p >0,05$).*

Sonuç: *Diz osteoartriti şiddeti, özellikle ağrı ve fiziksel fonksiyonda daha kötü yaşam kalitesi ile yakından ilişkilidir, ancak kas kuvveti ile ilişkili değildir. Bu bulgular, OA hastalarında propriyosepsiyonun geliştirilmesi ve ağrı yönetimine odaklanan rehabilitasyon programlarının önemini vurgulamaktadır.*

Anahtar kelimeler: *osteoartrit şiddeti; osteoartrit derecesi; diz propriyosepsiyonu; yaşam kalitesi; WOMAC; diz kas kuvveti*

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Introduction

Knee osteoarthritis (OA) is a degenerative joint disease characterized by the breakdown of articular cartilage and changes in subchondral bone, leading to pain, stiffness, and functional limitations. It is one of the most prevalent musculoskeletal disorders, particularly affecting the elderly population, and is a leading cause of disability worldwide and in our country[1]. The rising prevalence of knee OA with advancing age significantly affects the quality of life, often leading to reduced mobility, increased pain, and psychological distress [2].

There is growing evidence that osteoarthritis severity, particularly in the knee joint, is closely related to declines in muscle strength, particularly in the quadriceps and hamstrings. Studies have consistently shown that individuals with more severe OA tend to have significantly reduced muscle strength, which exacerbates joint instability and contributes to worsening symptoms such as pain and functional limitations[3]. This reduction in muscle strength is primarily attributed to both disuse and the catabolic effects of chronic inflammation on muscle tissue, further worsening physical function and increasing the risk of falls[4]. The quadriceps, in particular, play a vital role in knee joint stability, and weakness in this muscle group has been shown to correlate strongly with the progression of OA and with the severity of pain and stiffness experienced by patients. Therefore, strengthening interventions targeting the quadriceps and hamstrings are essential components of rehabilitation aimed at improving joint function and quality of life (QoL) in individuals with OA[5].

Proprioception, or the ability to sense the position and movement of the joints, is another factor often impaired in individuals with knee OA. This impairment can decrease balance and coordination, exacerbating functional limitations and increasing the risk of falls[6]. Proprioceptive deficits have been linked to reduced muscle strength, joint instability, and increased joint pain, all of which contribute to the decline in physical function and QoL in OA patients[7].

The impact of knee OA on health-related quality of life is multifaceted, encompassing physical, psychological, and social dimensions. Chronic pain, functional limitations, and reduced mobility can lead to psychological issues such as depression and anxiety, further diminishing quality of life[2]. Additionally, OA is associated with other comorbidities such as obesity, cardiovascular disease, and diabetes, which further complicate disease management and reduce life quality[3].

The relationship between OA severity and life quality is well-documented, with more severe radiographic changes correlating with greater functional impairment and lower life quality scores[1]. However, it is not only the structural changes in the joint that determine the patient's experience; the psychological and emotional aspects, such as coping mechanisms and social support, also play a significant role[2]. Recent studies have emphasized the need for a holistic approach to managing OA that addresses the disease's physical and psychological aspects[8,9].

Our study was conducted to address the growing need for understanding the intricate relationship between osteoarthritis severity and muscle strength, particularly in the quadriceps and hamstrings, proprioception and QoL. Our study explores the differences in knee muscle strength, proprioception, and QoL in individuals with bilateral knee OA and examines the relationship between these factors and OA severity.

Material and Methods

Study Design and Setting

This cross-sectional observational study was conducted between 1 October 2023 and 30 July 2024 at the Physical Medicine and Rehabilitation Unit of Atatürk University and Erzurum City Hospital. The Erzurum Technical University institutional review board approved the study protocol (ethic code: 06.09.2023, 10–2), and all participants provided written informed consent before inclusion in the study. Our study was conducted by the Declaration of Helsinki.

Participants

A total of 40 individuals with bilateral knee osteoarthritis (age 58.25±6.19 years, height 167.8±6.53 cm, weight 84.12±4.89 kg) were recruited for this study. Participants were selected based on the following inclusion criteria:

- Diagnosed with bilateral knee osteoarthritis (both extremities are the same grade) as per clinical and radiological findings.
- No psychological, mental, or neurological disorders.
- No lower extremity injuries in the last six months.
- Patients were excluded if they had systemic inflammatory conditions or other comorbidities that could affect the outcome measures.

Variables and Data Collection

Muscle Strength Measurement: Isometric hamstring and quadriceps muscle strength were measured using a hand-held dynamometer (La Fayette). Before the assessment, participants were seated with their hips and knees at 90° flexion to ensure a standardized and stable testing posture. The dynamometer was placed just above the ankle for quadriceps measurements and at the back of the lower leg for hamstring measurements. Participants were instructed to exert maximal isometric contraction against the dynamometer for 3 to 5 seconds. Three trials were performed for each muscle group, and the average force (in Newtons) was recorded. Adequate rest (approximately 1–2 minutes) was provided between trials to minimize fatigue[10].

Proprioception Assessment: Proprioception was assessed using a dual inclinometer through an active angle repetition test. The participants were actively moved into the reference positions (30° and 60°) and were asked to replicate these positions with their eyes closed[11]. A digital inclinometer (J-Tech Medical, Midvale, UT, USA) was used for precise measurement. Three trials were conducted, and the average position error for both knees was calculated. Proprioception measurements were taken before muscle strength assessments.

Osteoarthritis Severity: Knee X-rays were evaluated by a physical medicine and rehabilitation specialist according to the Kellgren-Lawrence classification[12]. Osteoarthritis severity was also determined using the Lequesne Algofunctional Knee Index, which evaluates pain, walking ability, and functional limitations in daily activities. Higher scores on this index indicate more functional impairment.

Quality of Life and Functional Status: The WOMAC (Western Ontario and McMaster Universities Osteoarthritis Index) assessed participants' quality of life and knee function. The WOMAC consists of three main sections and 24 questions assessing pain, stiffness, and physical function. Higher WOMAC scores indicate worse outcomes in all domains (pain, stiffness, and physical function)[13].

Procedures

Participants were given detailed verbal and visual explanations of the study procedures during the initial session. Each participant underwent a 5-minute warm-up with stretching exercises before the assessments. The warm-up consisted of dynamic stretching exercises targeting the quadriceps, hamstrings, and calf muscles**,** each performed for 30 seconds and repeated twice for a total warm-up duration of 5 minutes**.** The rationale for this protocol was to enhance muscle flexibility and joint mobility before testing. Demographic data, including age, gender, height, weight, and dominant leg, were recorded. After the warm-up, participants were verbally and visually informed about the measurement procedures, and proprioception and muscle strength assessments were performed in that order. All measurements were conducted by a physiotherapist with 15 years of experience in the field.

Statistical Analysis

Data were analyzed using IBM Statistical Package for Social Sciences (SPSS) program software version 20. Means, standard deviations, medians, and minimum-maximum values were calculated for the data. The chi-square test was used to compare categorical variables between groups. Pearson or Spearman correlation coefficients were calculated to assess the relationship between muscle strength, proprioception, and severity of osteoarthritis. A p-value of <0.05 was considered statistically significant.

Results

A total of 40 participants (45% male, 55% female) were included in the study, with an average age of 58.25±6.19 years, a minimum age of 45 years, and a maximum age of 80 years. The average body weight was 84.12±4.89 kg, with a median of 85 kg, a minimum of 55 kg, and a maximum of 111 kg. The participants' average height was 167.8±6.53 cm, with a minimum height of 150 cm and a maximum height of 190 cm. The duration of symptoms varied, with participants reporting an average duration of 5.70±4.9 years, a minimum of 1 year, and a maximum of 15 years (Table 1).

Table 1. *Demographic Information*

n: 40 (18 m, 22f)	Mean ± SD	Median	Min-Max
Age (years)	58.25±6.19	61	45–80
Body weight (kg)	84.12±4.89	85	55–111
Height (cm)	167.8±6.53	170	150–190
Duration of symptoms (years)	5.70±4.9	5	1–15

SD: Standart deviation, Min: Minimum, Max: Maximum

Table 2. Correlations of parameters (Spearman's rho)

Correlations																				
			ationofSympt	Age	Height	Body Weight	NDS-Quadriceps	DS-Quadriceps	NDS-Hamstring	DS-Hamstring	Lequesne	WomacPain	WomacStiffness	VOMACPhysicalFunctio	WOMACTotal	NDS Prop30	NDS Prop60	DS Prop30	DS Prop60
earman's r	Duration of Symptoms	r	1	0,595	0,153	-.878**	0,051	-0,096	0,209	0,019	0,198	0,085	.752*	-0,166	-0,057	-.665*	-0,561	.665*	-.761*
		p	.	0,069	0,672	0,001	0,889	0,793	0,562	0,958	0,584	0,815	0,012	0,646	0,876	0,036	0,092	0,036	0,011
	Age	r		1	0,203	-0,038	-0,144	-0,181	-0,12	-0,114	0,271	0,032	0,277	0,132	0,143	-0,106	0,174	.393*	-0,252
		p		.	0,21	0,818	0,394	0,29	0,485	0,509	0,09	0,844	0,083	0,415	0,378	0,539	0,31	0,018	0,139
	Height	r			1	.313*	.475**	.405*	0,313	0,314	-0,193	-0,159	-0,259	-0,077	-0,156	0,044	0,14	0,18	-0,013
		p			.	0,049	0,003	0,014	0,063	0,063	0,233	0,327	0,107	0,637	0,335	0,797	0,415	0,293	0,941
	Body Weight	r				1	0,309	0,185	0,17	.362*	-.421**	-0,105	-.353*	-0,03	-0,095	0,053	-0,303	-0,185	0,218
		p				.	0,063	0,279	0,323	0,03	0,007	0,521	0,025	0,854	0,561	0,757	0,073	0,279	0,202
	NDS- Quadriceps	r					1	.702**	.758**	.654**	-0,233	0,049	-0,175	0,071	0,064	-0,182	-0,242	-0,227	-0,146
		p					.	0	0	0	0,166	0,772	0,3	0,674	0,706	0,288	0,155	0,184	0,397
	DS- Quadriceps	r						1	.682**	.682**	-.546**	-0,321	-.354*	-0,224	-0,28	0,064	0,064	-0,282	0,005
		p						.	0	0	0,001	0,056	0,034	0,189	0,099	0,713	0,713	0,095	0,977
	NDS-Hamstring	r							1	.757**	-0,233	0,001	-0,085	0,09	0,047	0,019	-0,149	-0,266	-0,285
		p							.	0	0,172	0,995	0,623	0,603	0,785	0,911	0,386	0,118	0,092
	DS-Hamstring	r								1	-0,244	-0,176	-0,202	-0,143	-0,137	-0,07	-0,083	-0,296	-0,209
		p								.	0,151	0,306	0,237	0,404	0,427	0,685	0,632	0,079	0,221
	Lequesne	r									1	.754**	.744**	.668**	.740**	-0,313	-0,071	0,02	-.573**
		p									.	0	0	0	0	0,063	0,683	0,909	0
	WomacPain	r										1	.626**	.893**	.923**	-0,276	-.362*	-0,264	-.577**
		p										.	0	0	0	0,103	0,03	0,12	0
	WomacStiffness	r											1	.659**	.740**	-.413*	0,04	0,003	-.703**
		p											.	0	0	0,012	0,819	0,987	0
	WOMAC Physical Function	r												1	.977**	-0,175	-0,105	-0,254	-.468**
		p												.	0	0,307	0,543	0,136	0,004
	WOMAC Total	r													1	-0,31	-0,149	-0,188	-.552**
		p													.	0,065	0,385	0,272	0
	NDS Prop30	r														1	.361*	0,03	.522**
		p														.	0,031	0,864	0,001
	NDS Prop60	r															1	.341*	0,258
		p															.	0,042	0,128
	DS Prop30	r																1	0,216
		p																.	0,206
	DS Prop60	r																	1
		p																	.
** Correlation is significant at the 0.01 level (2-tailed).																			
* Correlation is significant at the 0.05 level (2-tailed).																			

A strong negative correlation was observed between symptom duration and body weight (r=-0.878, p<0.01). This suggests that body weight tends to decrease as the duration of symptoms increases. This could indicate that patients with more prolonged osteoarthritis symptoms may experience weight loss, potentially due to reduced mobility or other factors related to disease progression. Additionally, a moderate positive correlation exists between the duration of symptoms and WOMAC physical function scores (r=0.752, p=0.012). This indicates that longer symptom duration is associated with worse physical function, as measured by the WOMAC scale (Table 2).

The Lequesne index is significantly positively correlated with several WOMAC components, including WOMAC Pain (r=0.754, p<0.01), WOMAC Stiffness (r=0.744, p<0.01), WOMAC Physical Function (r=0.668, p<0.01) and WOMAC Total (r=0.740, p<0.01). These strong positive correlations suggest that higher Lequesne scores indicate worse osteoarthritis severity and are strongly associated with worse pain, stiffness, physical function, and overall WOMAC scores.

Body weight negatively correlates with several WOMAC and Lequesne scores (r=-0.421, p<0.01). These negative correlations suggest that patients with higher body weight tend to have lower Lequesne and WOMAC scores, which might imply less severe osteoarthritis symptoms or better physical function in this cohort.

The Lequesne Index, which measures the severity of osteoarthritis, showed a statistically significant difference between the groups (p<0.01). Group 4 had the highest average score (10.11), indicating worse symptoms, while Group 3 had a lower score (7.81).

WOMAC Pain: There was a significant increase in pain severity with higher osteoarthritis grades (p<0.01). Group 2 reported the lowest pain scores (3.40), while Group 4 reported the highest (7.33). WOMAC Stiffness was also significantly worse in the higher grade groups (p<0.05), with group 4 showing the most severe stiffness (2.85). A strong, significant deterioration in WOMAC Physical Function with increasing osteoarthritis severity (p<0.01). Group 4 had the most impaired function (29.00) compared to Group 2 (12.20). The total WOMAC score, combining pain, stiffness, and function, was significantly higher in groups 4 (39.18) and 3 (36.34) compared to group 2.00 (16.80) (p<0.01).

Table 3. *Relationship between osteoarthritis severity and other parameters*

N: 40	Grade 2 (Mean ± SD)	Grade 3 (Mean ± SD)	Grade 4 (Mean ± SD)	Chi-Square	p-value
Duration of symptoms	5.2±2.9	5.88±3.54	6.24±2.55	-	-
Age (Years)	54.40±7.64	60.58±10.12	53.67±10.34	0.611	0.435
Height (cm)	170.80±7.53	164.62±7.33	161.78±15.43	2.893	0.089
Body weight (kg)	87.20±8.53	84.88±9.04	80.22±19.32	0.088	0.767
NDS quadriceps (Nm)	25.53±11.28	21.59±6.36	23.24±8.58	0.017	0.895
DS quadriceps (Nm)	21.23±5.05	19.32±5.08	22.03±8.00	0.623	0.430
NDS hamstring (Nm)	16.79±6.79	14.34±7.55	13.94±1.54	0.010	0.921
DS hamstring (Nm)	15.17±4.14	13.68±4.13	13.18±3.56	0.846	0.358
Lequesne index	5.60±0.89	7.81±3.66	10.11±2.93	8.221	**0.004**
WOMAC pain	3.40±1.34	7.12±1.95	7.33±4.18	13.076	**0.001**
WOMAC stiffness	1.20±0.45	2.44±0.67	2.85±1.07	5.137	**0.023**
WOMAC physical function	12.20±3.38	26.77±4.91	29.00±6.24	12.267	**0.001**
WOMAC total	16.80±5.17	36.34±6.53	39.18±11.49	12.252	**0.001**
NDS proprioception 30°	2.50±0.58	2.17±1.89	2.92±1.39	1.120	0.290
NDS proprioception 60°	4.17±0.19	3.78±1.89	4.08±2.19	5.631	**0.018**
DS proprioception 30°	3.50±1.35	2.22±0.90	3.25±1.82	2.984	0.084
DS proprioception 60°	4.67±0.38	3.92±1.30	3.08±1.34	9.237	**0.002**

DS: Dominant side, NDS: Non-dominant side

US Proprioception at 60° showed a significant decrease with increasing osteoarthritis severity ($p<0.05$), with group 3 reporting a mean of 3.78 and group 4 a mean of 4.08, compared to 6.17 in group 2. AS Proprioception at 60° also demonstrated a significant decline ($p=0.002$), with group 4.00 showing the lowest score (3.08) compared to group 2.00 (6.67) (Table 3).

These results indicate that as osteoarthritis grade increases, patients experience significantly worse outcomes in pain, stiffness, physical function, and proprioception, particularly at larger joint angles (60°). Muscle strength did not show significant differences between the groups, suggesting that while quadriceps and hamstring strength may not directly correlate with osteoarthritis grade, functional impairment and proprioception are more closely associated with disease severity. The significant increase in WOMAC and Lequesne scores with higher grades of osteoarthritis further reinforces the impact of osteoarthritis on overall quality of life.

Discussion

Our study aimed to explore the relationship between osteoarthritis (OA) severity and muscle strength, proprioception, and overall quality of life. While the severity of osteoarthritis increased, no weakening of quadriceps and hamstring muscle strength was observed. As the severity of osteoarthritis increased, the WOMAC index, which measures pain, stiffness and physical function of the individuals, increased. Additionally, no proprioception deficit was observed on the dominant side but just the non-dominant side 60°.

The relationship between osteoarthritis (OA) severity and muscle strength, particularly in the quadriceps and hamstrings, has been explored extensively in recent literature. Numerous studies have demonstrated that individuals with more severe OA typically exhibit greater muscle weakness, which exacerbates functional limitations and increases disability[14,15]. Both the quadriceps and hamstring muscles play crucial roles in stabilizing the knee joint, and their weakening contributes to the progression of OA[16]. Quadriceps weakness, in particular, has been identified as a primary factor in the progression of OA. Studies show that lower quadriceps strength is associated with higher grades of OA, increased pain levels, and poorer functional outcomes. This weakness is often more pronounced in individuals with advanced radiographic stages of OA[3,15]. Moreover, a systematic review and meta-analysis found that lower knee extensor strength increases the risk of OA structural worsening, especially in women[15]. Although often less emphasized than quadriceps strength, hamstring

strength is also critical. Studies have shown that imbalances between hamstring and quadriceps strength (H/Q ratio) can further destabilize the knee joint, increasing the risk of joint damage. Targeted strengthening of both muscle groups, rather than just the quadriceps, has improved functional outcomes in individuals with OA[17,18]. As a result of our study, we found no decrease in muscle strength with osteoarthritis severity. Takagi et al.[19] emphasized in their study that knee muscle strength was associated with radiographic OA incidence but not with its progression. Additionally, while muscle strength is an essential factor for joint function, studies have also pointed out that muscle cocontraction patterns, proprioception, and neuromuscular control might contribute more to functional impairment in OA than just pure muscle strength alone. These findings imply that muscle strength may not always decrease linearly with increasing OA severity[20]. These results are parallel to our study.

The relationship between proprioception and OA severity has been well-documented in recent studies. Individuals with more severe OA tend to experience greater proprioceptive impairments, especially in joint position sense (JPS) and motion sense[21]. As OA progresses, proprioceptive accuracy decreases due to the degeneration of joint structures, including mechanoreceptors in the knee, which play a critical role in detecting joint position and movement[22,23]. This decline in proprioception is associated with increased functional limitations and a higher risk of falls due to reduced neuromuscular control[7]. Moreover, proprioceptive impairments have been correlated with increased pain and disability, as they reduce the ability to stabilize the knee joint during movement[24]. These impairments also exacerbate muscle weakness, particularly in the quadriceps, further compounding functional difficulties[25]. Considering the findings from our study, a significant reduction in proprioception was observed on just the non-dominant side of 60°. No changes were observed in the dominant extremity and other angles. Two research has found no significant difference in proprioceptive acuity between more and less painful knees in OA patients, indicating that proprioception may not directly correlate with the degree of OA-related joint deterioration[26,27]. This challenges the assumption that proprioception consistently worsens as OA progresses, suggesting that other factors, such as pain, muscle strength, or neuromuscular control, might play a more critical role in proprioceptive function. While proprioception may not always align with OA severity, it is still crucial in maintaining balance and preventing falls. Studies show that proprioceptive impairments may be more related to joint pain and instability than the radiographic severity of OA[27].

WOMAC is a validated tool widely used to assess patient-reported OA-related outcomes, particularly in the knees and hips. As OA severity increases, patients typically report higher WOMAC scores across all subscales (pain, stiffness, and physical function), correlating with worsening symptoms and disability[28,29]. Our study shows that patients with more severe radiographic OA tend to have significantly higher WOMAC scores, indicating greater impairment. This supports that OA's progression directly impacts quality of life, with pain and functional limitations being the most affected aspects. Furthermore, the WOMAC index is sensitive to even small changes in OA severity, making it a reliable tool for capturing the clinical significance of worsening symptoms[30]. The studies by Ribeiro et al.[9] and Khalil et al.[31] demonstrated a positive correlation between higher KL grades and elevated WOMAC scores, particularly in patients with moderate to severe OA. All these results are consistent with the results of our study.

A relatively small sample size (n=40) may limit the generalizability of the results to broader populations. Furthermore, while the study assessed both dominant and non-dominant sides for proprioception, it did not explore other potentially influential factors, such as physical activity levels, comorbidities, or variations in pain management that could affect the outcomes. Additionally, the reliance on self-reported measures like the WOMAC index, while valuable, can introduce subjective bias in assessing pain and functional impairment. The strengths of our study are the use of validated tools like the Kellgren-Lawrence classification, the Lequesne Algofunctional Knee Index, and the WOMAC index, which enhances the study's reliability and comparability with other research. Another strength is the standardization of measurement protocols for muscle strength and proprioception, which were performed by an experienced physiotherapist, ensuring consistency and minimizing measurement bias.

Conclusion

Our study has demonstrated that increasing osteoarthritis (OA) severity is strongly associated with higher WOMAC scores, indicating worsening pain, stiffness,

and physical function. Notably, while proprioception impairments were evident, they did not correlate uniformly with OA grade, suggesting that other factors may influence joint stability and balance. Despite these findings, muscle strength, particularly in the quadriceps and hamstrings, did not significantly decline across OA severity, highlighting the need for further research into the role of neuromuscular control in OA progression.

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References

1. Muraki S, Akune T, Oka H, et al. Association of radiographic and symptomatic knee osteoarthritis with health-related quality of life in a population-based cohort study in Japan: the ROAD study. Osteoarthritis and cartilage. 2010;18:1227–34.
2. Park HM, Kim HS, Lee YJ. Knee osteoarthritis and its association with mental health and health-related quality of life: a nationwide cross-sectional study. Geriatrics & Gerontology International. 2020;20:379–83.
3. Ruhdorfer A, Wirth W, Hitzl W, Nevitt M, Eckstein F, Investigators OI. Association of thigh muscle strength with knee symptoms and radiographic disease stage of osteoarthritis: data from the Osteoarthritis Initiative. Arthritis care & research. 2014;66:1344–53.
4. Khalaj N, Abu Osman NA, Mokhtar AH, Mehdikhani M, Wan Abas WAB. Balance and risk of fall in individuals with bilateral mild and moderate knee osteoarthritis. PloS one. 2014;9:e92270.
5. Özüdoğru A, Gelecek N. Effects of closed and open kinetic chain exercises on pain, muscle strength, function, and quality of life in patients with knee osteoarthritis. Revista da Associação Médica Brasileira. 2023;69:e20230164.
6. Bennell KL, Hinman RS, Metcalf BR, et al. Relationship of knee joint proprioception to pain and disability in individuals with knee osteoarthritis. Journal of orthopaedic research. 2003;21:792–7.
7. Van der Esch M, Steultjens M, Harlaar J, Knol D, Lems W, Dekker J. Joint proprioception, muscle strength, and functional ability in patients with osteoarthritis of the knee. Arthritis Care & Research: Official Journal of the American College of Rheumatology. 2007;57:787–93.
8. Pai YC, Rymer WZ, Chang RW, Sharma L. Effect of age and osteoarthritis on knee proprioception. Arthritis & Rheumatism: Official Journal of the American College of Rheumatology. 1997;40:2260–5.
9. Ribeiro IC, Coimbra AMV, Costallat BL, Coimbra IB. Relationship between radiological severity and physical and mental health in elderly individuals with knee osteoarthritis. Arthritis Research & Therapy. 2020;22:1–7.
10. Mellemkjær FH, Madeleine P, Nørgaard JE, Jørgensen MG, Kristiansen M. Assessing Isometric Quadriceps and Hamstring Strength in Young Men and Women: Between-Session Reliability and Concurrent Validity. Applied Sciences. 2024;14:958.
11. Akaras E, Çobanoğlu G, Suner-keklik S, et al. Changes in Physical Fitness Parameters with Increasing Age. Research in Sport Education and Sciences. 2024;26:88–97.
12. Kohn MD, Sassoon AA, Fernando ND. Classifications in brief: Kellgren-Lawrence classification of osteoarthritis. Clinical Orthopaedics and Related Research®. 2016;474:1886–93.
13. Tüzün E, Eker L, Aytar A, Daşkapan A, Bayramoğlu M. Acceptability, reliability, validity and responsiveness of the Turkish version of WOMAC osteoarthritis index. Osteoarthritis and cartilage. 2005;13:28–33.
14. Omori G, Koga Y, Tanaka M, et al. Quadriceps muscle strength and its relationship to radiographic knee osteoarthritis in Japanese elderly. Journal of orthopaedic science. 2013;18:536–42.
15. Patterson BE, Girdwood MA, West TJ, et al. Muscle strength and osteoarthritis of the knee: a systematic review and meta-analysis of longitudinal studies. Skeletal radiology. 2023;52:2085–97.
16. Al-Johani AH, Kachanathu SJ, Hafez AR, et al. Comparative study of hamstring and quadriceps strengthening treatments in the management of knee osteoarthritis. Journal of physical therapy science. 2014;26:817–20.
17. Purba TSP, Moeliono MA, Sastradimadja SB. Effect of quadriceps muscle strengthening exercise on quadriceps and hamstring muscle strength ratio in patients with osteoarthritis grade 2 and 3. International Journal of Integrated Health Sciences. 2017;5:64–9.
18. Aslan Ö, Batur EB, Meray J. The importance of functional hamstring/quadriceps ratios in knee osteoarthritis. Journal of sport rehabilitation. 2019;29:866–70.
19. Takagi S, Omori G, Koga H, et al. Quadriceps muscle weakness is related to increased risk of radiographic knee OA but not its progression in both women and men: the Matsudai Knee Osteoarthritis Survey. Knee Surgery, Sports Traumatology, Arthroscopy. 2018;26:2607–14.
20. Luc-Harkey BA, Safran-Norton CE, Mandl LA, Katz JN, Losina E. Associations among knee muscle strength, structural damage, and pain and mobility in individuals with osteoarthritis and symptomatic meniscal tear. BMC musculoskeletal disorders. 2018;19:1–11.
21. Sharma L, Pai Y-C. Impaired proprioception and osteoarthritis. Current opinion in rheumatology. 1997;9:253–8.
22. Knoop J, Steultjens M, Van der Leeden M, et al. Proprioception in knee osteoarthritis: a narrative review. Osteoarthritis and cartilage. 2011;19:381–8.
23. Mani E, Tüzün EH, Angın E, Eker L. Lower extremity proprioceptive sensation in patients with early stage knee osteoarthritis: a comparative study. The Knee. 2020;27:356–62.
24. de Oliveira DCS, Barboza SD, da Costa FD, Cabral MP, Silva VMP, Dionisio VC. Can pain influence the proprioception and the motor behavior in subjects with mild and moderate knee osteoarthritis? BMC musculoskeletal disorders. 2014;15:1–8.

25. Ramirez DS, van der Leeden M, Knol DL, et al. Association of postural control with muscle strength, proprioception, self-reported knee instability and activity limitations in patients with knee osteoarthritis. Journal of rehabilitation medicine. 2013;45:192–7.
26. Lee S-S, Kim H-J, Ye D, Lee D-H. Comparison of proprioception between osteoarthritic and age-matched unaffected knees: a systematic review and meta-analysis. Archives of Orthopaedic and Trauma Surgery. 2021;141:355–65.
27. Kim D, Park G, Kuo L-T, Park W. The effects of pain on quadriceps strength, joint proprioception and dynamic balance among women aged 65 to 75 years with knee osteoarthritis. BMC geriatrics. 2018;18:1–6.
28. Kwon SB, Ku Y, Han H-S, Lee MC, Kim HC, Ro DH. A machine learning-based diagnostic model associated with knee osteoarthritis severity. Scientific Reports. 2020;10:15743.
29. Wailoo A, Hernandez Alava M, Escobar Martinez A. Modelling the relationship between the WOMAC osteoarthritis index and EQ-5D. Health and quality of life outcomes. 2014;12:1–6.
30. Bellamy N, Wells G, Campbell J. Relationship between severity and clinical importance of symptoms in osteoarthritis. Clinical rheumatology. 1991;10:138–43.
31. Khalil NFW, El-sherif S, El Hamid MMA, Elnemr R, Taleb RSZ. Role of global femoral cartilage in assessing severity of primary knee osteoarthritis. Egyptian Rheumatology and Rehabilitation. 2022;49:16.