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Impact of Inner Range Strengthening of the Knee in Functional Outcomes of Patients with Early Osteoarthritis of the Knee - A Quasi-Experimental

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ABSTRACT

Background:

Osteoarthritis (OA) of the knee is a leading cause of pain and functional limitation among adults, particularly in the early stages when conservative interventions can delay disease progression. Quadriceps muscle weakness, particularly of the vastus medialis oblique (VMO), plays a significant role in the pathomechanics of knee OA. This quasi-experimental study aimed to evaluate the effectiveness of inner range quadriceps strengthening exercises on functional outcomes in patients with early-stage knee OA.

Methods:

A total of 60 participants aged between 40 and 60 years with clinically diagnosed early knee OA were recruited and divided into intervention (n=30) and control (n=30) groups. The intervention group underwent a structured inner range quadriceps strengthening protocol for 12 weeks, while the control group received conventional knee exercises without specific inner range strengthening. Outcome measures including Visual Analogue Scale (VAS) for pain, Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), and Short Form-36 (SF-36) Physical Function scores were assessed at baseline and post-intervention. Statistical analysis involved descriptive statistics and inferential statistics (within-group and between-group analysis) using paired and unpaired t-tests.

Results:

The intervention group demonstrated statistically significant improvements in VAS, WOMAC, and SF-36 scores compared to the control group ($p<0.001$). Within-group analysis also revealed marked functional improvements post-intervention in the intervention group, while minimal changes were observed in the control group.

Conclusion:

Inner range quadriceps strengthening exercises significantly improve pain, function, and quality of life in patients with early knee OA. Incorporating these exercises in rehabilitation protocols can serve as an effective non-invasive management strategy.

Key words - Knee Osteoarthritis, Inner Range Strengthening, Quadriceps Muscle, Functional Outcomes, Pain Reduction, Rehabilitation Exercises.

1. Introduction

Osteoarthritis (OA) of the knee is a prevalent degenerative joint disease that significantly impairs mobility and quality of life among adults worldwide. Characterized by the progressive breakdown of articular cartilage, knee OA leads to pain, stiffness, and functional limitations. (1) Early intervention strategies are crucial to mitigate disease progression and enhance

patient outcomes.Quadriceps strengthening exercises have been extensively studied for their role in managing knee OA. Strengthening the quadriceps can improve knee joint stability and reduce pain. (2,3) However, the specific impact of inner range quadriceps exercises—targeting the vastus medialis oblique (VMO) muscle—on functional outcomes in early-stage knee OA remains underexplored. (4) The VMO plays a critical role in patellar tracking and knee stabilization, suggesting that focused strengthening in this region may offer unique benefits. (5) Previous research has demonstrated the effectiveness of general quadriceps strengthening in improving pain and function in knee OA patients. (6) For instance, a randomized clinical trial reported significant improvements in pain and quality of life following an eight-week quadriceps strengthening program.(7,8) Additionally, combining quadriceps exercises with modalities like neuromuscular electrical stimulation (NMES) has shown enhanced outcomes in individuals with knee OA. (9) Despite these findings, there is a paucity of studies focusing specifically on inner range quadriceps strengthening and its direct effects on functional outcomes in early knee OA. (10) This quasi-experimental study aims to bridge this gap by evaluating the impact of an inner range quadriceps strengthening program on functional outcomes in patients with early-stage knee OA. We hypothesize that targeted inner range exercises will lead to significant improvements in knee function, pain reduction, and overall quality of life in this patient population.

2. Methods

Study Design

A quasi-experimental design was employed to assess the effectiveness of inner range quadriceps strengthening exercises on functional outcomes in patients with early knee OA. Participants were assigned to either an intervention group, which received the targeted exercise program, or a control group, which did not receive any specific intervention.

Participants

Participants were recruited from outpatient clinics specializing in musculoskeletal disorders. Inclusion criteria were:

- Age between 40 and 65 years
- Clinical diagnosis of early-stage knee OA based on the American College of Rheumatology criteria
- Experiencing knee pain for at least three months
- Ability to provide informed consent and comply with the study protocol

Exclusion criteria included:

- History of knee surgery or significant knee trauma
- Inflammatory joint diseases
- Participation in other knee rehabilitation programs during the study period

Intervention

The intervention group participated in a 12-week inner range quadriceps strengthening program focusing on the VMO muscle. Exercises included:

1. **Inner Range Quadriceps Contractions**: Performed with the knee positioned at 30 degrees of flexion to specifically target the VMO.
2. **Straight Leg Raises with External Rotation**: Aimed at activating the VMO by externally rotating the hip during the leg raise.

3. **Mini Squats**: Executed within a limited range of motion to emphasize inner range quadriceps activation.

4. **Step-Downs**: Performed from a low step to engage the VMO during controlled descent.

Participants performed these exercises three times per week under the supervision of a physiotherapist. Each session lasted approximately 45 minutes and included warm-up and cool-down periods.

Outcome Measures

Primary outcomes assessed were:

- **Knee Pain**: Measured using the Visual Analog Scale (VAS), ranging from 0 (no pain) to 10 (worst imaginable pain).
- **Functional Ability**: Evaluated using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), which assesses pain, stiffness, and physical function.
- **Quality of Life**: Assessed with the Short Form-36 (SF-36) questionnaire, covering various health domains.

Secondary outcomes included quadriceps muscle strength, measured using a handheld dynamometer, and knee joint range of motion, assessed with a goniometer.

Data Collection and Analysis

Assessments were conducted at baseline and after the 12-week intervention period. Descriptive statistics summarized participant characteristics and baseline measures. Inferential statistics, including paired and independent t-tests, analyzed within-group and between-group differences, respectively. A significance level of $p<0.05$ was set for all analyses.

3. Results

Participant Characteristics

A total of 60 participants were enrolled, with 30 in each group. Baseline characteristics are presented in Table 1.

Table 1: Baseline Characteristics of Participants

Characteristic	**Intervention Group (n=30)**	**Control Group (n=30)**
Age (years), mean (SD)	55.2 (6.1)	54.8 (5.9)
Gender (M/F)	12/18	11/19
BMI (kg/m²), mean (SD)	27.5 (3.2)	27.8 (3.5)
Duration of Symptoms (months)	10.4 (2.1)	10.1 (2.3)

Functional Outcomes

Post-intervention assessments revealed significant improvements in the intervention group compared to the control group. Detailed results are shown in Table 2.

Results (Continued)

Table 2: Within-Group Analysis of Functional Outcomes

Outcome Measure	Time Point	Intervention Group Mean (SD)	Control Group Mean (SD)	p-value	95% CI for p-value
VAS Pain Score	Baseline	6.5 (1.2)	6.3 (1.3)	0.412	0.278 – 0.552
	Post-Test	3.2 (1.1)	5.9 (1.4)	<0.001	0.000 – 0.004
WOMAC Score	Baseline	45.2 (5.8)	44.8 (6.1)	0.734	0.543 – 0.921
	Post-Test	24.5 (5.3)	38.9 (6.7)	<0.001	0.000 – 0.003
SF-36 Physical Function	Baseline	61.3 (8.5)	60.9 (8.2)	0.834	0.624 – 0.978
	Post-Test	78.4 (8.7)	66.3 (9.1)	<0.001	0.000 – 0.006

Table 3: Between-Group Analysis of Functional Outcomes

Outcome Measure	Intervention Group Mean (SD)	Control Group Mean (SD)	Mean Difference	p-value	95% CI for Mean Difference
VAS Pain Score	3.2 (1.1)	5.9 (1.4)	-2.7	<0.001	-3.31 to -2.09
WOMAC Score	24.5 (5.3)	38.9 (6.7)	-14.4	<0.001	-16.92 to -11.88
SF-36 Physical Function	78.4 (8.7)	66.3 (9.1)	12.1	<0.001	8.93 to 15.26

4. Discussion

The present quasi-experimental study aimed to evaluate the impact of inner range quadriceps strengthening exercises on the functional outcomes of patients with early-stage knee osteoarthritis (OA). The results unequivocally demonstrated that a 12-week inner range strengthening protocol significantly improved knee function, reduced pain, and enhanced the quality of life in the intervention group compared to the control group. (11,12)

Knee OA is one of the leading causes of disability in the aging population. Its multifactorial etiology includes biomechanical, genetic, and metabolic factors that lead to cartilage degradation, joint space narrowing, and osteophyte formation. Muscle weakness, particularly of the quadriceps, has been strongly correlated with the development and progression of knee OA (6-10). Inner range quadriceps strengthening, focusing primarily on the vastus medialis oblique (VMO), is biomechanically important as the VMO plays a pivotal role in patellar tracking and medial knee stabilization. (13,14)

The findings of the present study corroborate earlier research that emphasized the significance of quadriceps strengthening in improving functional outcomes in OA patients. Specifically, the mean VAS pain score in the intervention group reduced

significantly from 6.5 to 3.2 ($p<0.001$), while the control group showed minimal improvement. Similar patterns were observed in WOMAC scores and SF-36 scores, indicating enhanced functional ability and quality of life in the intervention group.(15) Several mechanisms can explain these improvements. First, inner range exercises primarily activate the VMO, which enhances patellar alignment, reduces lateral patellar tracking, and minimizes compressive forces on the joint surfaces (16-19). This leads to decreased pain and mechanical stress on the joint. Second, increased quadriceps strength stabilizes the knee during gait and functional activities, reducing joint load and improving mobility (20-23).

The between-group analysis highlighted statistically significant differences across all outcome measures, with p-values less than 0.001 and confidence intervals favoring the intervention group. These results suggest a clinically meaningful improvement that could substantially benefit early OA patients if adopted in clinical practice. While the present study provides compelling evidence, it has some limitations. The quasi-experimental design lacks randomization, which may introduce selection bias. Additionally, the follow-up period was limited to 12 weeks, so the long-term effects of inner range strengthening exercises remain unknown. Future studies should consider randomized controlled trials with larger sample sizes and extended follow-up periods to validate these findings. (24,25)

Despite these limitations, the study adds valuable knowledge to the existing literature by emphasizing the role of targeted inner range quadriceps exercises in early knee OA management. (26) Given that early OA is the most appropriate phase to implement conservative interventions, these exercises can delay or even prevent disease progression, ultimately reducing the need for pharmacological or surgical interventions. (27)

Our findings are consistent with other studies that reported similar outcomes using broader quadriceps strengthening protocols (29,30). However, the unique focus on inner range exercises addresses the often-overlooked role of the VMO, offering a more precise and potentially more effective therapeutic strategy.

5. Conclusion

In conclusion, this quasi-experimental study demonstrates that inner range quadriceps strengthening significantly improves functional outcomes in patients with early osteoarthritis of the knee. The intervention led to notable reductions in pain, enhancements in functional ability, and improvements in quality of life. These findings underscore the importance of early and targeted muscle strengthening as a non-invasive, cost-effective strategy in the management of knee OA. Incorporating inner range exercises into standard rehabilitation protocols may offer substantial benefits and delay disease progression.

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