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EFFECT OF A COMBINED STATIONARY CYCLING AND THERAPEUTIC EXERCISE PROGRAM ON HEALTH-RELATED QUALITY OF LIFE IN ELDERLY INDIVIDUALS WITH KNEE OSTEOARTHRITIS: A QUASI-EXPERIMENTAL STUDY

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Abstract

Background

Knee osteoarthritis (KOA) is a leading cause of pain, disability, and impaired quality of life among older adults. Exercise therapy is recommended as the first-line conservative treatment; however, evidence regarding the combined effect of Stationary cycling and therapeutic exercises on patient-reported outcomes in elderly individuals remains limited.

Objective

To evaluate the effect of a combined stationary cycling and therapeutic exercise program on pain, symptoms, functional status, and knee-related quality of life in elderly individuals with knee osteoarthritis.

Methods

A prospective quasi-experimental pre–post interventional study was conducted among 51 elderly participants with Grade I or II knee osteoarthritis recruited from two outpatient physiotherapy centers in Islamabad, Pakistan. Participants underwent a supervised six-week rehabilitation program comprising stationary cycling and therapeutic exercises, delivered three sessions per week. Outcomes were assessed before and after the intervention using the Knee Injury and Osteoarthritis Outcome Score (KOOS), including pain, symptoms, activities of daily living (ADL), sport and recreation, and knee-related quality of life. Data

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was analyzed using paired-samples t-tests, with statistical significance set at $p < 0.05$.

Results

Significant improvements were observed across all KOOS domains following the intervention (all $p < 0.001$). Mean pain scores improved from 53.82 ± 13.61 to 74.41 ± 15.99, symptoms from 52.73 ± 15.88 to 69.03 ± 15.65, ADL from 51.12 ± 16.43 to 70.57 ± 16.35, sport and recreation from 29.63 ± 18.71 to 47.04 ± 23.33, and knee-related quality of life from 38.58 ± 16.92 to 65.22 ± 18.42. The greatest relative improvement was observed in the quality-of-life domain.

Conclusion

A six-week supervised program combining stationary cycling and therapeutic exercises significantly improved pain, functional status, and knee-related quality of life among elderly individuals with knee osteoarthritis. These findings support the integration of low-impact aerobic exercise with therapeutic exercise as an effective conservative rehabilitation strategy for managing knee osteoarthritis.

INTRODUCTION

Knee osteoarthritis (KOA) is the most prevalent degenerative joint disorder and one of the leading causes of chronic pain, disability, and reduced quality of life among older adults worldwide. It is characterized by progressive degeneration of the articular cartilage, remodeling of subchondral bone, osteophyte formation, synovial inflammation, and deterioration of surrounding soft tissues, ultimately resulting in impaired joint function and mobility. As global life expectancy continues to increase, the prevalence of KOA is rising substantially, making it an important public health concern with significant clinical and socioeconomic implications. Recent estimates suggest that hundreds of millions of people are living with osteoarthritis globally, with the knee being the most frequently affected weight-bearing joint. The burden is expected to increase further because of population ageing, increasing obesity, sedentary lifestyles, and longer life expectancy. Consequently, KOA has become one of the major contributors to years lived with disability among older adults and places considerable demands on healthcare systems worldwide (1-4).

The pathological process of knee osteoarthritis extends beyond the degeneration of articular cartilage. The disease affects the entire joint complex, including the synovium, menisci, ligaments, periarticular muscles, and subchondral bone. Mechanical stress combined with biochemical and inflammatory mechanisms accelerates cartilage degradation and alters normal joint biomechanics, producing pain, stiffness, muscle weakness, instability, and restricted range of motion. These structural and functional changes progressively compromise an individual's ability to perform routine physical activities and diminish overall independence. Disease progression varies considerably among individuals and is influenced by multiple interacting factors including age, sex, obesity, previous knee trauma, metabolic disorders, muscle weakness, and abnormal joint loading patterns (2, 5-8).

Age remains one of the strongest predictors of knee osteoarthritis because age-related biological changes reduce the regenerative capacity of cartilage while simultaneously increasing susceptibility to mechanical damage. Elderly individuals frequently experience progressive deterioration in muscle mass, neuromuscular control, proprioception, and balance, all of which contribute to impaired joint stability and functional decline. Sarcopenia further compounds these impairments by reducing lower-limb strength, particularly in the quadriceps muscles, thereby increasing joint loading during daily activities. Reduced muscular support around

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the knee accelerates structural degeneration and contributes to pain, reduced walking ability, impaired stair negotiation, and diminished participation in social and recreational activities. These factors collectively reduce independence and substantially impair health-related quality of life in older adults (6-10).

Pain represents the principal symptom prompting individuals with KOA to seek medical care. Persistent pain is frequently accompanied by morning stiffness, reduced walking tolerance, decreased endurance, and limitations in performing activities of daily living such as sitting, standing, stair climbing, dressing, and household tasks. Functional disability often leads to reduced physical activity, initiating a cycle of progressive muscle weakness, joint stiffness, physical deconditioning, and worsening symptoms. As disease severity increases, many individuals experience social isolation, emotional distress, anxiety, and depression, highlighting that KOA affects not only physical function but also psychological well-being and overall quality of life. Contemporary evidence therefore recognizes health-related quality of life as one of the most important measures when evaluating conservative interventions for knee osteoarthritis (11-14).

Quality of life encompasses physical, psychological, and social dimensions of health and reflects an individual's perception of their functional capabilities within everyday life. In patients with KOA, reductions in quality of life are strongly associated with increasing pain severity, physical disability, decreased mobility, reduced participation in recreational activities, and diminished independence. Consequently, modern management strategies increasingly emphasize interventions that improve functional performance and quality of life rather than focusing solely on symptom reduction. Patient-reported outcome measures such as the Knee Injury and Osteoarthritis Outcome Score (KOOS) have therefore become valuable tools for evaluating pain, symptoms, activities of daily living, sport and recreation function, and knee-related quality of life from the patient's perspective. These multidimensional assessments provide a comprehensive understanding of treatment outcomes and functional status (15-17).

Current international clinical practice guidelines consistently recommend conservative management as the first-line treatment for individuals with mild-to-moderate knee osteoarthritis. Exercise therapy remains the cornerstone of conservative rehabilitation because it addresses multiple impairments simultaneously, including pain, muscle weakness, joint stiffness, reduced mobility, and physical inactivity. Various forms of exercise, including strengthening exercises, flexibility training, aerobic conditioning, balance exercises, neuromuscular training, and functional rehabilitation—have demonstrated beneficial effects on pain relief and physical function. Exercise also promotes weight management, improves cardiovascular fitness, enhances confidence during movement, and encourages long-term self-management, making it one of the most effective non-pharmacological interventions for KOA (18).

Among strengthening interventions, particular emphasis has traditionally been placed on the quadriceps muscles because quadriceps weakness is consistently associated with pain, functional decline, and disease progression. However, emerging evidence indicates that rehabilitation should not focus exclusively on the knee joint. Hip musculature, trunk stability, proprioceptive training, and gait retraining also influence lower-limb biomechanics and contribute to improved functional outcomes. Strengthening the muscles surrounding the hip and lower extremity may reduce abnormal knee loading during walking and other weight-bearing activities, thereby enhancing movement efficiency and reducing symptom severity. Contemporary rehabilitation program therefore advocate comprehensive lower-limb strengthening rather than isolated muscle training (5, 7).

Cycling has gained increasing attention as a safe, low-impact aerobic exercise for individuals with knee osteoarthritis. Unlike high-impact activities, cycling enables repetitive knee motion while minimizing excessive compressive forces across the tibiofemoral joint. The cyclic movement promotes

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joint lubrication through improved synovial fluid circulation, facilitates maintenance of knee range of motion, enhances muscular endurance, and improves cardiovascular fitness without imposing excessive mechanical stress on degenerative joint surfaces. Cycling may therefore represent an ideal exercise modality for elderly individuals who experience pain during prolonged walking or weight-bearing activities. Both stationary and outdoor cycling have demonstrated potential to improve lower-limb function while maintaining acceptable levels of joint loading, making cycling an attractive component of comprehensive rehabilitation program (12, 14).

The combination of cycling with structured therapeutic exercises may provide additional clinical benefits because these interventions target complementary physiological mechanisms. While strengthening and flexibility exercises improve muscle performance, joint stability, balance, and functional movement patterns, cycling contributes aerobic conditioning, repetitive joint mobility, muscular endurance, and improved confidence during movement. Integrating these approaches may facilitate greater improvements in pain, physical function, and overall quality of life than either intervention alone. Several randomized controlled trials and systematic reviews have reported positive effects of exercise-based rehabilitation on pain reduction, physical function, walking performance, and patient-reported outcomes in individuals with KOA. Nevertheless, variations in exercise protocols, intervention intensity, duration, participant characteristics, and outcome measures continue to limit direct comparison between studies, highlighting the need for further investigation in different populations and healthcare settings (13, 18).

Despite substantial evidence supporting exercise therapy for knee osteoarthritis, relatively fewer studies have specifically examined the combined contribution of cycling and therapeutic exercises among elderly populations in low- and middle-income countries. Differences in healthcare access, socioeconomic status, cultural practices, patient adherence, and rehabilitation resources may influence treatment outcomes and quality of life. Furthermore, patient-reported functional outcomes remain underreported in many regional settings, emphasizing the need to evaluate these interventions using validated outcome measures such as the KOOS questionnaire. Understanding the functional status and quality of life of elderly individuals receiving physiotherapy may help clinicians optimize rehabilitation strategies and support evidence-based clinical decision-making within routine practice.

Therefore, the present study was undertaken to evaluate the impact of cycling and therapeutic exercises on the quality of life of elderly people with knee osteoarthritis. Specifically, the study aimed to assess pain, symptoms, activities of daily living, sport and recreational function, and knee-related quality of life using the Knee Injury and Osteoarthritis Outcome Score (KOOS). By examining these patient-reported outcomes, this study sought to provide evidence regarding the potential contribution of cycling combined with therapeutic exercise in improving functional health and quality of life among elderly individuals with knee osteoarthritis.

OBJECTIVES

Primary Objective

To determine the effect of a combined cycling and therapeutic exercise program on the quality of life among elderly individuals with knee osteoarthritis.

Secondary Objectives

- To evaluate the effect of combined cycling and therapeutic exercises on knee pain in elderly individuals with knee osteoarthritis.
- To determine the effect of the intervention on knee-related symptoms and stiffness.
- To assess changes in activities of daily living following the intervention.
- To evaluate improvements in sports and recreational function after the intervention.
- To assess changes in overall knee-related quality of life using the Knee Injury and Osteoarthritis Outcome Score (KOOS).

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MATERIALS AND METHODS

Study Design

A prospective quasi-experimental interventional study with a pre-test and post-test design was conducted to evaluate the effectiveness of a combined cycling and therapeutic exercise program on the quality of life of elderly individuals with knee osteoarthritis. Outcome measures were assessed at baseline before initiation of the intervention and after completion of the treatment program.

Study Setting

The study was conducted at the Department of Physiotherapy, National Institute of Rehabilitation Medicine (NIRM), and Islamabad Physiotherapy and Rehabilitation Centre, Islamabad, Pakistan. Both centers provide outpatient physiotherapy services for individuals with musculoskeletal disorders, including knee osteoarthritis.

Study Duration

The study was conducted over a period of 3 months following approval of the research protocol by the institutional authorities. Participant recruitment, intervention delivery, and outcome assessment were completed within the study period.

Ethical Considerations

Ethical approval was obtained from the Institutional Review Board of Riphah College of Rehabilitation Sciences, Riphah International University, Islamabad, Pakistan, before commencement of the study. Written informed consent was obtained from all participants prior to enrollment. Participants were informed about the study objectives, intervention procedures, potential benefits, confidentiality of personal information, and their right to withdraw from the study at any stage without affecting their routine clinical care. The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.

Participants

Elderly individuals clinically diagnosed with Grade I or Grade II knee osteoarthritis according to the Kellgren–Lawrence classification were recruited from the outpatient physiotherapy departments of the participating centers.

Inclusion Criteria

Participants were eligible if they:

- were between 50 and 70 years of age;
- had unilateral or bilateral Grade I or Grade II knee osteoarthritis diagnosed clinically and radiographically;
- reported knee pain during functional activities for at least three months;
- were able to ambulate independently with or without an assistive device;
- were medically fit to participate in an exercise program; and
- provided written informed consent.

Exclusion Criteria

Participants were excluded if they:

- had Grade III or Grade IV knee osteoarthritis;
- had undergone previous knee arthroplasty or recent lower-limb surgery;
- had inflammatory arthritis, rheumatoid arthritis, gout, or other systemic musculoskeletal disorders;
- had neurological disorders affecting gait or balance;
- had unstable cardiovascular or respiratory conditions contraindicating exercise;
- had severe cognitive impairment preventing compliance with the intervention; or
- were currently participating in another structured physiotherapy or exercise program.

Sample Size

A total of 51 participants who met the eligibility criteria were enrolled in the study using a non-probability purposive sampling technique. All eligible participants who consented during the study period were included in the intervention.

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Intervention Protocol

All participants received a standardized supervised rehabilitation program combining stationary cycling and therapeutic exercises. The intervention was delivered three times per week for six weeks, with each session lasting approximately 45–60 minutes. Every treatment session included a warm-up, stationary cycling, therapeutic exercises, and a cool-down. A detailed description of the intervention protocol and assessment timeline is presented in **Table 1**.

Table 1. Study intervention protocol and assessment timeline for participants undergoing a supervised stationary cycling and therapeutic exercise program.

Study Phase	Procedure	Description
Pre-intervention (Baseline Assessment)	Participant screening	Participants were screened according to the predefined inclusion and exclusion criteria. Written informed consent was obtained before enrollment.
	Demographic assessment	Baseline demographic and clinical characteristics, including age, gender, body weight, history of diabetes mellitus, and hypertension, were recorded.
	Baseline outcome assessment	The Knee Injury and Osteoarthritis Outcome Score (KOOS) questionnaire was administered before initiation of the intervention to assess pain, symptoms, activities of daily living, sport and recreation function, and knee-related quality of life.
Intervention Phase	Warm-up (5–10 min)	Participants performed a standardized warm-up consisting of active range-of-motion exercises and gentle stretching of the lower-limb musculature under physiotherapist supervision.
	Cycling program (15–20 min)	Participants received supervised stationery cycling as part of the rehabilitation program. Cycling intensity was individualized according to each participant's functional ability and symptom tolerance to improve knee mobility and lower-limb endurance while minimizing excessive joint stress.

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	Therapeutic exercise program (20–30 min)	Participants performed a standardized therapeutic exercise program comprising knee range-of-motion exercises, quadriceps and hamstring strengthening, hip strengthening, lower-limb stretching, balance and proprioceptive training, and functional mobility exercises. Exercise progression was individualized according to participants' clinical response and functional capacity.
	Cool-down (5 min)	Each treatment session concluded with gentle stretching and relaxation exercises to facilitate recovery following the intervention.
	Treatment schedule	The rehabilitation program was delivered three sessions per week for six consecutive weeks, with each treatment session lasting approximately 45–60 minutes.
Post-intervention	Outcome assessment	Following completion of the intervention program, the KOOS questionnaire was re-administered using the same standardized procedure to evaluate changes in pain, symptoms, activities of daily living, sport and recreation function, and knee-related quality of life.
	Statistical analysis	Baseline and post-intervention KOOS scores were compared to evaluate changes in clinical and functional outcomes following the intervention.

Outcome Measure

The primary outcome of this study was knee-related quality of life, assessed using the Knee Injury and Osteoarthritis Outcome Score (KOOS) questionnaire. The KOOS is a validated, self-administered, patient-reported outcome measure specifically developed to evaluate short- and long-term symptoms and functional status in individuals with knee osteoarthritis. It comprises five domains: pain, symptoms, activities of daily living (ADL), sport and recreation function, and knee-related quality of life. Each domain is scored separately on a scale from 0 to 100, with higher scores indicating better knee health, functional performance, and quality of life. The KOOS has demonstrated excellent validity, reliability, and

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responsiveness, making it a widely accepted instrument for assessing clinical outcomes and monitoring treatment effectiveness in patients with knee osteoarthritis

Data Collection Procedure

Eligible participants were screened according to the predefined inclusion and exclusion criteria. Following informed consent, demographic and clinical information including age, gender, body weight, history of diabetes mellitus, and hypertension were recorded using a structured data collection form. Baseline assessment was performed using the KOOS questionnaire before initiation of the intervention. Participants subsequently completed the prescribed cycling and therapeutic exercise program under physiotherapist supervision. At the completion of the intervention period, the KOOS questionnaire was re-administered using the same standardized procedure. All assessments were performed by trained assessors to minimize measurement bias.

Statistical Analysis

Data was entered and analyzed using IBM Statistical Package for the Social Sciences (SPSS) version 26.0. Continuous variables were assessed for normality using the Shapiro–Wilk test and visual inspection of histograms and Q–Q plots. Normally distributed continuous variables were summarized as mean ± standard deviation (SD), whereas categorical variables were presented as frequencies and percentages. Changes in KOOS domain scores between baseline and post-intervention assessments were analyzed using paired-samples *t*-tests for normally distributed data. Whereas assumptions of normality were violated, the Wilcoxon signed-rank test was applied. Statistical significance was established at a two-tailed p value < 0.05. Effect sizes and 95% confidence intervals were calculated to determine the magnitude and precision of treatment effects.

RESULTS

Participant Characteristics

A total of 60 individuals were assessed for eligibility, of whom 51 met the inclusion criteria and were enrolled in the study. Nine participants were excluded because they did not meet the eligibility criteria (n = 5) or declined to participate (n = 4). All enrolled participants completed the six-week intervention and post-intervention assessment and were included in the final analysis (Figure 1).

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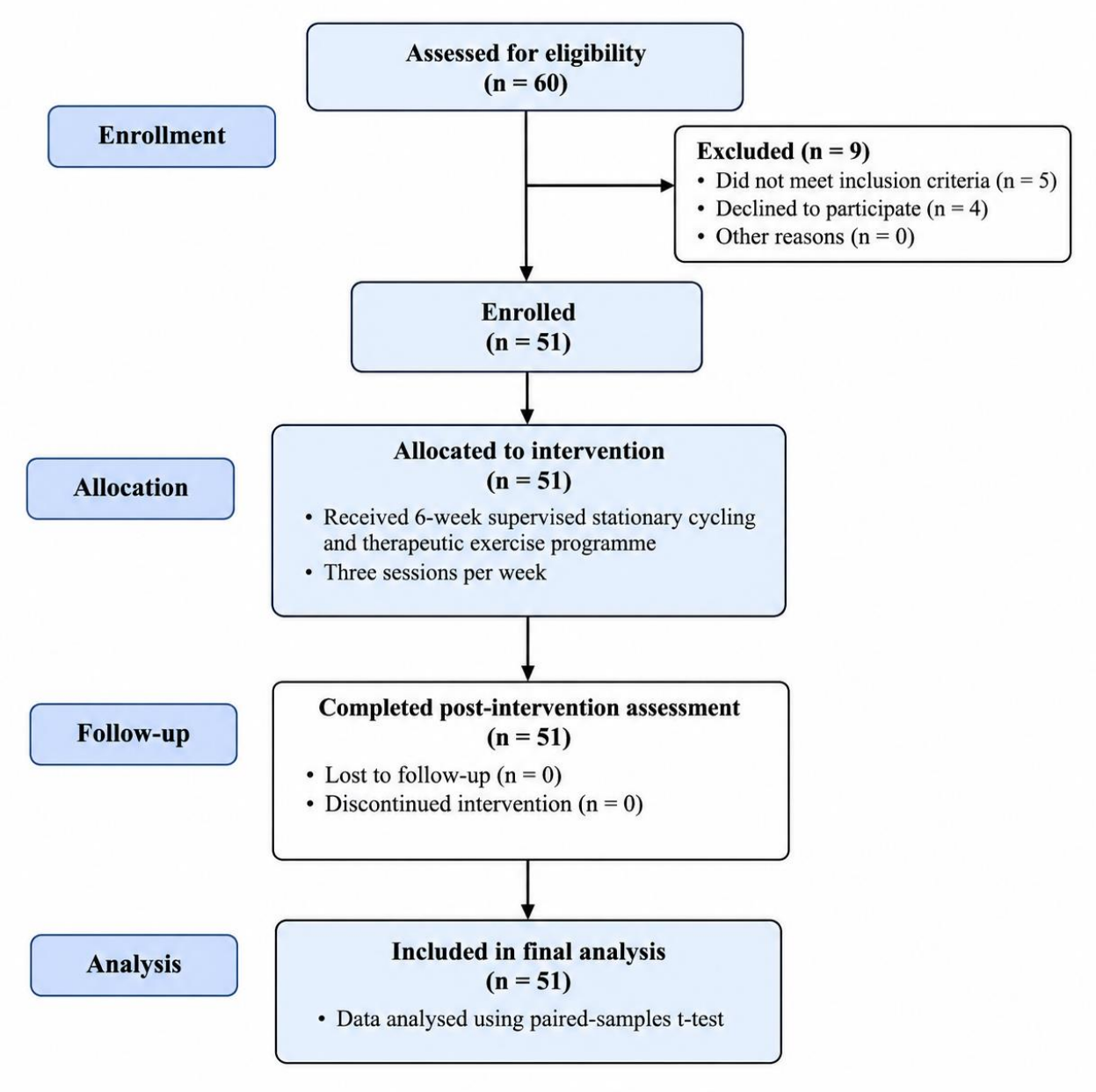

Figure 1. Flow diagram illustrating participant recruitment, eligibility assessment, enrollment, intervention, follow-up, and inclusion in the final statistical analysis.

The baseline demographic and clinical characteristics of the participants are presented in Table 2. The mean age of the participants was 58.80 ± 7.76 years, and the mean body weight was 72.98 ± 11.18 kg. Females comprised most of the study population (72.5%), while males accounted for 27.5%. Additionally, 45.1% of the participants had diabetes mellitus and 49.0% had hypertension (Table 2).

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Table 2. Baseline demographic and clinical characteristics of the participants (N = 51)

Variable	Value
Age (years), Mean ± SD	58.80 ± 7.76
Weight (kg), Mean ± SD	72.98 ± 11.18
Male, n (%)	14 (27.5)
Female, n (%)	37 (72.5)
Diabetes mellitus, n (%)	23 (45.1)
Hypertension, n (%)	25 (49.0)

Effect of Cycling and Therapeutic Exercises on KOOS Outcomes

The comparison of pre- and post-intervention KOOS scores demonstrated improvements across all outcome domains following the six-week cycling and therapeutic exercise program (Table 3). Statistically significant improvements were observed in pain, symptoms, activities of daily living, sports and recreational function, and knee-related quality of life (all $p < 0.001$), as illustrated in Figure 2.

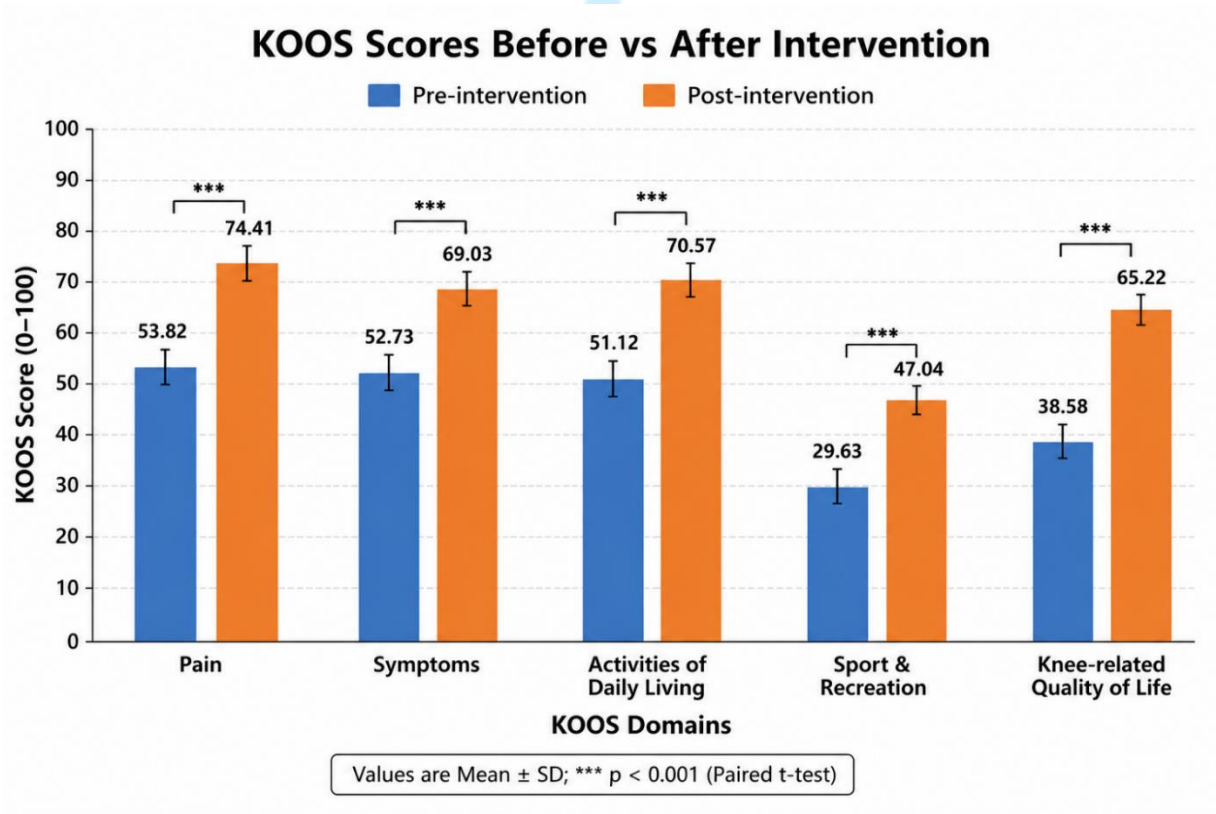

Figure 2. Comparison of KOOS scores before and after the six-week intervention.

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As shown in Table 3, the mean Pain score increased from 53.82 ± 13.61 before the intervention to 74.41 ± 15.99 after the intervention, with a mean improvement of 20.59 points (95% CI: 15.92–23.26; p < 0.001). The Symptoms score improved from 52.73 ± 15.88 to 69.03 ± 15.65, representing a mean increase of 16.30 points (95% CI: 14.74–21.86; p < 0.001). Similarly, the Activities of Daily Living score increased from 51.12 ± 16.43 at baseline to 70.57 ± 16.35 following the intervention, with a mean improvement of 19.45 points (95% CI: 17.46–25.44; p < 0.001). The Sports and Recreation domain also demonstrated improvement, increasing from 29.63 ± 18.71 to 47.04 ± 23.33, corresponding to a mean difference of 17.41 points (95% CI: 14.06–24.76; p < 0.001). The greatest absolute improvement was observed in Knee-related Quality of Life, where the mean score increased from 38.58 ± 16.92 to 65.22 ± 18.42, with a mean difference of 26.64 points (95% CI: 20.37–28.91; p < 0.001).

Table 3. Comparison of KOOS scores before and after intervention

KOOS Domain	Pre-intervention Mean ± SD	Post-intervention Mean ± SD	Mean Difference	95% CI	p-value
Pain	53.82 ± 13.61	74.41 ± 15.99	20.59	15.92–23.26	<0.001
Symptoms	52.73 ± 15.88	69.03 ± 15.65	16.30	14.74–21.86	<0.001
Activities of Daily Living	51.12 ± 16.43	70.57 ± 16.35	19.45	17.46–25.44	<0.001
Sports & Recreation	29.63 ± 18.71	47.04 ± 23.33	17.41	14.06–24.76	<0.001
Knee-related Quality of Life	38.58 ± 16.92	65.22 ± 18.42	26.64	20.37–28.91	<0.001

Paired-Samples t-Test Analysis of KOOS Outcome Measures

The paired samples t-test confirmed that the observed improvements in all KOOS domains were statistically significant (Table 4). The largest improvement was observed in the Quality-of-Life domain (26.64 ± 9.54, t = 18.47, p < 0.001), followed by Pain (20.59 ± 8.24, t = 16.98, p < 0.001) and Activities of Daily Living (19.45 ± 9.11, t = 16.76, p < 0.001). Significant improvements were also found in Sports and Recreation (17.41 ± 10.83, t = 12.81, p < 0.001) and Symptoms (16.30 ± 8.76, t = 14.92, p < 0.001). These findings indicate that the intervention produced statistically significant improvements across all measured domains.

Table 4. Paired-samples t-test

Outcome	Mean Difference ± SD	t-value	df	p-value
Pain	20.59 ± 8.24	16.98	50	<0.001
Symptoms	16.30 ± 8.76	14.92	50	<0.001
Activities of Daily Living	19.45 ± 9.11	16.76	50	<0.001
Sports & Recreation	17.41 ± 10.83	12.81	50	<0.001
Quality of Life	26.64 ± 9.54	18.47	50	<0.001

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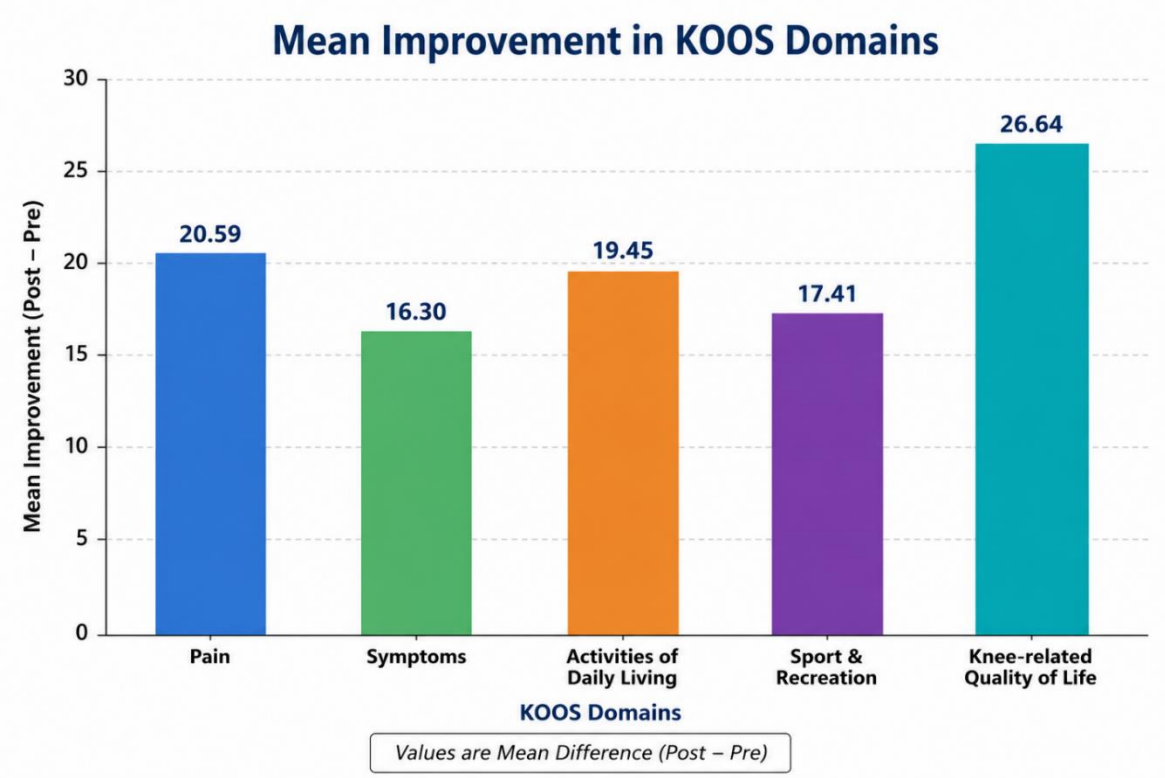

Figure 3. Mean improvement in KOOS domains following the intervention.

Percentage Improvement in KOOS Outcome Measures

Table 5 presents the percentage improvement in KOOS scores following the intervention. The greatest relative improvement was observed in Knee-related Quality of Life, which improved by 69.1%. This was followed by Sports and Recreation with a 58.8% improvement. Pain and Activities of Daily Living improved by 38.3% and 38.0%, respectively, while the Symptoms domain showed a 30.9% improvement. Overall, these findings demonstrate clinically meaningful improvements in all KOOS domains after completion of the six-week rehabilitation program.

Table 5. Percentage improvement

KOOS Domain	Baseline Score	Post-intervention Score	Percentage Improvement
Pain	53.82	74.41	38.3%
Symptoms	52.73	69.03	30.9%
Activities of Daily Living	51.12	70.57	38.0%
Sports & Recreation	29.63	47.04	58.8%
Knee-related Quality of Life	38.58	65.22	69.1%

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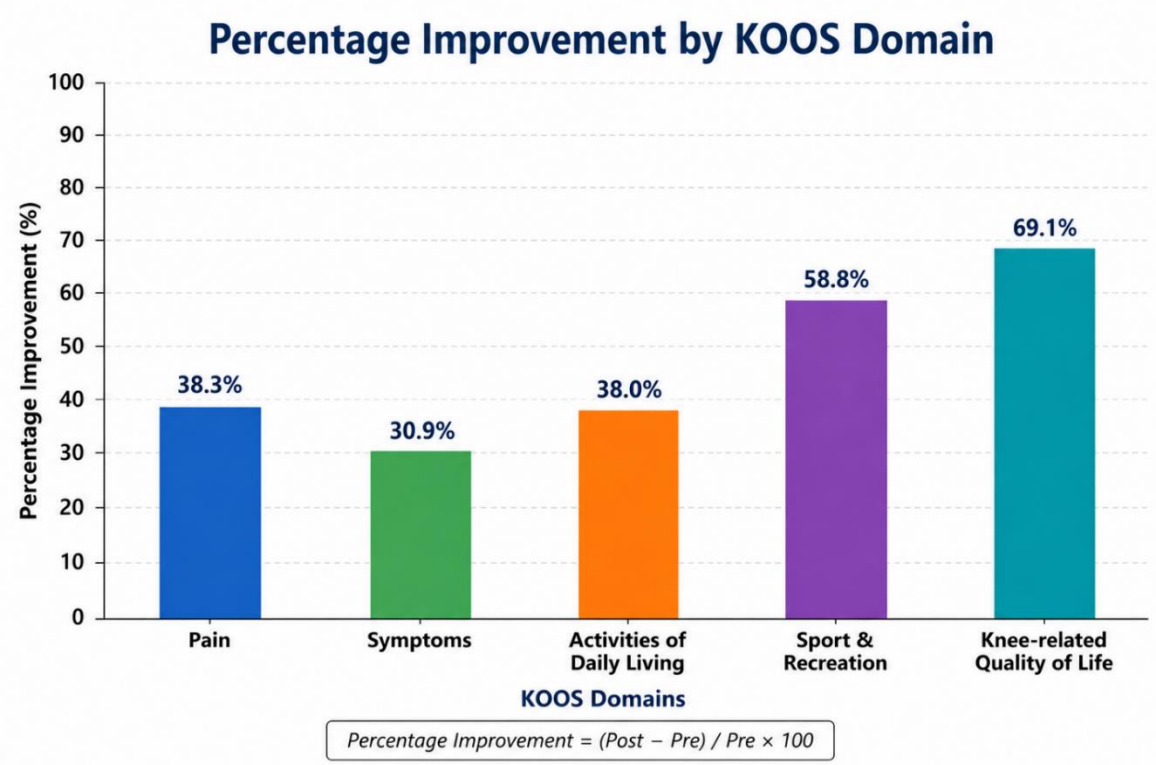

Figure 4. Percentage improvement across KOOS domains following the intervention.

DISCUSSION

The present study evaluated the effectiveness of a six-week supervised rehabilitation program combining stationary cycling with therapeutic exercises in improving pain, functional status, and health-related quality of life among elderly individuals with knee osteoarthritis. Significant improvements were observed across all domains of the Knee Injury and Osteoarthritis Outcome Score (KOOS), including pain, symptoms, activities of daily living, sport and recreation function, and knee-related quality of life. Among these outcomes, the greatest improvement was observed in the quality-of-life domain, suggesting that the intervention produced benefits extending beyond symptom relief to broader aspects of physical function and overall well-being. Collectively, these findings indicate that integrating low-impact aerobic exercise with therapeutic exercises provides a comprehensive rehabilitation approach capable of addressing multiple impairments associated with knee osteoarthritis simultaneously. Rather than targeting pain alone, the intervention appeared to enhance functional independence, movement confidence, and perceived health status, supporting current recommendations that emphasize exercise-based physiotherapy as the cornerstone of conservative management for knee osteoarthritis.

One of the principal findings of the present study was the significant improvement in the pain domain following completion of the intervention. Participants demonstrated a clinically meaningful increase in KOOS pain scores after six weeks of rehabilitation, indicating substantial pain reduction during daily activities. This improvement is particularly important because persistent pain represents the primary factor limiting mobility, reducing physical activity, and contributing to progressive functional decline among individuals with knee osteoarthritis. Effective pain control is therefore essential not only for symptom management but also for restoring movement, encouraging participation in rehabilitation, and preventing the cycle of

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inactivity that accelerates muscle weakness and disability.

The observed reduction in pain is consistent with contemporary international clinical practice guidelines, which identify structured exercise therapy as the first-line conservative treatment for knee osteoarthritis. The American College of Rheumatology (ACR) and the Osteoarthritis Research Society International (OARSI) recommend aerobic exercise, strengthening exercises, and neuromuscular training because these interventions consistently reduce pain while improving physical function with minimal adverse effects. Similarly, the updated Cochrane systematic review by Fransen et al. concluded that structured exercise programs produce moderate to large improvements in pain regardless of the specific exercise modality employed. Our findings therefore reinforce the growing consensus that appropriately prescribed exercise remains one of the most effective non-pharmacological interventions for symptomatic knee osteoarthritis (11, 12, 15).

The magnitude of pain reduction observed in the present study is also comparable with findings reported in previous randomized controlled trials evaluating exercise-based rehabilitation. Juhl et al. demonstrated that exercise programs tailored to individual functional capacity significantly reduce pain and disability, with greater treatment effects observed when exercise intensity and progression are appropriately prescribed. Likewise, Bennell and Hinman emphasized that improvements in muscular strength, neuromuscular control, and joint stability collectively reduce pain by enhancing movement efficiency and minimizing abnormal mechanical loading of the knee joint. The similarity between our findings and previous evidence suggests that the rehabilitation program implemented in the present study achieved clinically meaningful pain relief through mechanisms that are consistent with established physiological principles of exercise therapy (4, 5, 16).

Several physiological mechanisms may explain the observed improvement in pain. Stationary cycling provides repetitive, low-impact movement that promotes synovial fluid circulation, improves cartilage nutrition, and maintains joint mobility while avoiding excessive compressive forces across the tibiofemoral joint. Simultaneously, therapeutic exercises strengthen the quadriceps, hamstrings, and hip musculature, improving dynamic joint stability and reducing abnormal biomechanical stress during weight-bearing activities. Improvements in muscle strength are also likely to decrease reflex muscle inhibition commonly associated with chronic pain, thereby enhancing movement efficiency and reducing nociceptive stimulation. Collectively, these adaptations contribute to pain reduction while enabling patients to tolerate greater levels of physical activity with less discomfort.

From a clinical perspective, these findings support incorporating supervised stationary cycling into conventional physiotherapy programs for elderly individuals with mild-to-moderate knee osteoarthritis. Because cycling is inexpensive, low impact, and well tolerated by older adults, it offers a practical method of increasing aerobic conditioning while simultaneously promoting knee mobility. When combined with therapeutic exercises targeting muscular strength and functional performance, this approach may facilitate earlier restoration of mobility and improve adherence to rehabilitation programs. Consequently, clinicians should consider integrating cycling as a routine component of comprehensive conservative management rather than using strengthening exercises alone.

Beyond pain reduction, the present study also demonstrated significant improvement in the symptom's domain of the KOOS questionnaire. Participants reported reductions in joint stiffness, swelling, and mechanical symptoms following completion of the intervention, indicating that the rehabilitation program improved overall joint function rather than simply reducing pain intensity. Improvement in these symptoms is clinically meaningful because prolonged stiffness and impaired joint mobility frequently delay movement initiation, restrict walking ability, and reduce confidence during functional activities, particularly among older adults. Reducing these

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symptoms may therefore contribute substantially to improved mobility and independence in everyday life.

The improvement observed in the symptom's domain is consistent with current understanding of knee osteoarthritis as a disorder involving the entire joint rather than isolated cartilage degeneration. Hunter and Bierma-Zeinstra emphasized that symptom severity is influenced by multiple interacting factors, including synovial inflammation, muscle weakness, altered biomechanics, and impaired neuromuscular control. Similarly, Katz et al. reported that exercise-based rehabilitation improves subjective symptoms by restoring functional movement patterns and reducing mechanical stress across the joint rather than reversing structural degeneration. The agreement between the present findings and previous literature suggests that comprehensive rehabilitation addressing multiple impairments is more likely to produce meaningful symptomatic improvement than interventions targeting a single physiological component (13, 14).

The mechanisms underlying symptom improvement are likely multifactorial. The repetitive cyclic motion provided by stationary cycling facilitates joint lubrication and maintains knee range of motion, thereby reducing stiffness following periods of inactivity. Concurrently, stretching exercises improve soft-tissue flexibility, while strengthening exercises enhance muscular support around the knee, reducing excessive joint loading during functional tasks. Balance and proprioceptive training may further improve movement coordination and joint stability, enabling participants to perform daily activities with greater confidence and fewer mechanical symptoms. These combined physiological adaptations provide a plausible explanation for the consistent improvements observed in the symptom's domain following the intervention.

The reduction in symptoms observed in this study has important implications for physiotherapy practice. Improvements in stiffness and perceived joint function may increase patients' willingness to remain physically active, thereby promoting long-term adherence to exercise and reducing the risk of progressive disability. Since symptom improvement often precedes gains in physical function, these findings provide a foundation for understanding the subsequent improvements observed in activities of daily living, which are discussed in the following section.

The present study also demonstrated significant improvement in the Activities of Daily Living (ADL) domain following the six-week rehabilitation program. Participants reported greater ease in performing routine functional tasks, including walking, stair negotiation, standing from a seated position, and other everyday activities that are commonly affected by knee osteoarthritis. Improvement in ADL is particularly important because functional independence is a major determinant of healthy ageing and overall quality of life. Elderly individuals with knee osteoarthritis frequently experience progressive limitations in mobility that reduce social participation, increase dependence on caregivers, and diminish overall physical activity. Therefore, the substantial improvement observed in the ADL domain indicates that the intervention translated symptom reduction into meaningful functional gains that are directly relevant to patients' daily lives.

The improvement in functional performance observed in the present study is consistent with previous evidence supporting exercise-based rehabilitation for knee osteoarthritis. Pisters et al. reported that adherence to structured exercise programs was associated with sustained improvements in physical functioning and long-term clinical outcomes among individuals with hip and knee osteoarthritis. Likewise, Brosseau et al. demonstrated that community-based aerobic exercise programs significantly enhanced walking ability and overall physical functioning in patients with mild-to-moderate knee osteoarthritis. More recently, Quicke et al. concluded that greater participation in physical activity is consistently associated with improved functional performance and lower disability among individuals with knee osteoarthritis. The agreement between the present findings and previous research reinforces the

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effectiveness of structured rehabilitation programs in restoring functional independence and highlights the importance of maintaining regular physical activity throughout disease management (7, 8, 17).

Several physiological mechanisms may explain the observed improvement in activities of daily living. Strengthening exercises targeting the quadriceps, hamstrings, hip abductors, and surrounding lower-limb musculature improve force generation and dynamic joint stability, thereby reducing mechanical stress during weight-bearing activities. At the same time, stationary cycling enhances muscular endurance and cardiovascular fitness while maintaining repetitive, low-impact movement that preserves joint mobility. Improvements in balance and proprioception further optimize gait mechanics and movement coordination, allowing participants to perform functional activities more efficiently and with greater confidence. Collectively, these adaptations reduce the physical effort required for routine activities and enable elderly individuals to regain independence in everyday tasks.

From a clinical perspective, improvements in activities of daily living represent one of the most meaningful outcomes of rehabilitation because they directly influence patients' independence, community participation, and overall quality of life. The findings of the present study suggest that integrating stationary cycling with therapeutic exercises may accelerate restoration of functional capacity and reduce disability among elderly individuals with mild-to-moderate knee osteoarthritis. Consequently, physiotherapists should consider combining aerobic conditioning with strengthening and functional training to maximize improvements in daily functional performance rather than focusing solely on pain reduction.

In addition to improvements in routine daily activities, the present study demonstrated statistically significant improvement in the Sports and Recreation domain of the KOOS questionnaire following completion of the intervention. Although baseline scores in this domain were lower than those observed in other KOOS subscales, participants experienced one of the largest relative improvements after the rehabilitation program. This finding suggests that the intervention enhanced participants' confidence and physical capacity to perform activities requiring greater levels of endurance, balance, and dynamic movement. For older adults, improvement in this domain should not necessarily be interpreted as a return to competitive sporting activities; rather, it reflects increased ability to engage in recreational walking, outdoor activities, prolonged community ambulation, and other physically demanding tasks that contribute to active and healthy ageing.

These findings are consistent with previous literature demonstrating that comprehensive exercise programs improve higher-level physical performance among individuals with knee osteoarthritis. Fransen et al. reported that structured exercise interventions enhance mobility, endurance, and functional performance across multiple domains, including activities requiring greater physical demand. Similarly, Bennell and Hinman emphasized that improvements in muscular strength, proprioception, and neuromuscular coordination enable individuals with knee osteoarthritis to perform more challenging physical activities with reduced pain and greater confidence. The consistency between the present findings and previous evidence suggests that combining aerobic exercise with therapeutic strengthening provides broader functional benefits than interventions focusing on isolated impairments alone (15, 16).

The substantial improvement observed in the Sports and Recreation domain may be explained by several complementary physiological adaptations. Enhanced lower-limb muscle strength improves the capacity to tolerate repetitive loading during prolonged activities, while improved cardiovascular endurance enables participants to sustain physical activity for longer durations without excessive fatigue. Balance and proprioceptive exercises contribute to greater postural control and confidence movement, reducing fear of falling and encouraging participation in recreational activities. In addition,

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pain reduction likely played an important mediating role by removing a major barrier to physical activity, allowing participants to progressively increase their participation in more demanding functional tasks throughout the rehabilitation program.

The improvement in this domain also has important clinical implications. Fear of movement and activity avoidance are common among elderly individuals with knee osteoarthritis and often contribute to physical deconditioning, social isolation, and declining health. By improving confidence in movement and increasing tolerance for recreational activities, comprehensive rehabilitation programs may help patients adopt a more physically active lifestyle, thereby supporting long-term disease management and reducing future disability. These broader functional benefits extend beyond traditional clinical outcomes and reinforce the importance of incorporating multidimensional exercise programs into routine physiotherapy practice.

The greatest improvement observed in the present study was in the Knee-related Quality of Life (QoL) domain, which served as the primary outcome measure. Participants demonstrated marked improvements in their perception of knee health, functional capability, and overall well-being following the intervention. Because quality of life reflects the combined effects of pain, physical function, mobility, independence, emotional well-being, and participation in everyday activities, improvement in this domain suggests that the rehabilitation program produced meaningful benefits extending beyond isolated symptom reduction. Rather than simply decreasing pain intensity, the intervention appeared to improve participants' confidence, functional independence, and ability to engage in daily life, highlighting the patient-centered value of comprehensive rehabilitation.

The substantial improvement in quality of life observed in this study is consistent with contemporary concepts of osteoarthritis management that emphasize patient-reported outcomes as key indicators of treatment effectiveness. Katz et al. highlighted that successful management of knee osteoarthritis should be evaluated not only through clinical or radiographic findings but also by improvements in patient-perceived health status and functional capability. Similarly, Hunter and Bierma-Zeinstra emphasized that exercise-based rehabilitation improves quality of life through multiple interacting physiological and psychosocial mechanisms, including reduced pain, enhanced mobility, improved self-efficacy, and increased participation in social activities. The close agreement between the present findings and previous research supports the growing recognition that quality of life should remain a primary objective of conservative rehabilitation programs rather than a secondary treatment outcome (13, 14).

The marked improvement in quality of life observed in the present study is likely attributable to the cumulative benefits achieved across all other KOOS domains. Improvements in pain, reduction in stiffness, restoration of functional independence, and increased participation in recreational activities collectively enhance patients' perception of their overall health and well-being. Furthermore, supervised rehabilitation may have improved participants' confidence in managing their condition, encouraged regular physical activity, and promoted a greater sense of independence, all of which contributed positively to health-related quality of life. This multidimensional improvement illustrates the interconnected nature of patient-reported outcomes and demonstrates that successful rehabilitation should aim to improve overall function rather than addressing symptoms in isolation.

Taken together, the improvements observed in activities of daily living, sports and recreation, and knee-related quality of life indicate that the combined stationary cycling and therapeutic exercise program produced broad functional benefits extending beyond pain relief alone. These findings support the concept that comprehensive exercise-based rehabilitation can positively influence multiple dimensions of health in elderly individuals with knee osteoarthritis. Building on

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these findings, the following section discusses the underlying physiological mechanisms, broader clinical implications, strengths and limitations of the study, and directions for future research.

The favorable outcomes observed in the present study are likely the result of multiple complementary physiological mechanisms associated with the combined stationary cycling and therapeutic exercise program Unlike interventions that target a single impairment, the rehabilitation protocol simultaneously addressed aerobic capacity, muscle strength, joint mobility, neuromuscular control, balance, and functional movement patterns. Stationary cycling provided repetitive, low-impact knee motion that promoted synovial fluid circulation, facilitated cartilage nutrition, maintained joint range of motion, and improved cardiovascular endurance while minimizing excessive mechanical loading of the tibiofemoral joint. Concurrently, therapeutic exercises strengthened the quadriceps, hamstrings, hip musculature, and other stabilizing muscles, thereby enhancing dynamic joint stability and reducing abnormal biomechanical stresses during functional activities. Balance and proprioceptive training further improved movement coordination and postural control, enabling participants to perform daily activities more efficiently and with greater confidence. The combined effect of these physiological adaptations likely explains the consistent improvements observed across all KOOS domains rather than isolated improvements in pain or physical function alone.

The multidimensional nature of the intervention is particularly important because knee osteoarthritis is increasingly recognized as a whole-joint disorder rather than a disease confined to articular cartilage. Pain, muscle weakness, impaired proprioception, altered biomechanics, and reduced physical activity interact to accelerate functional decline and negatively influence quality of life. Therefore, rehabilitation strategies that simultaneously target these impairments are more likely to produce clinically meaningful outcomes than interventions addressing a single component of the disease. The present findings support this contemporary rehabilitation model by demonstrating that aerobic conditioning with strengthening and functional exercises can improve patient-reported outcomes across multiple dimensions of health.

The findings of this study have important clinical implications for physiotherapy practice and conservative management of knee osteoarthritis. As the global burden of osteoarthritis continues to increase with population ageing, there is a growing need for rehabilitation strategies that are effective, affordable, and feasible within routine clinical practice. The intervention evaluated in the present study requires only a stationary bicycle and standard physiotherapy equipment, making it practical for implementation in outpatient rehabilitation departments, community physiotherapy clinics, and primary healthcare settings. Because both stationary cycling and therapeutic exercises are low-impact, well tolerated, and easily individualized according to patient ability, they can be incorporated into rehabilitation programs for elderly individuals with mild-to-moderate knee osteoarthritis without requiring expensive technology or specialized facilities.

The results also reinforce current international clinical practice guidelines that recommend exercise as the cornerstone of conservative management for knee osteoarthritis. While strengthening exercises have traditionally formed the foundation of physiotherapy programs, the present findings suggest that incorporating low-impact aerobic exercise such as stationary cycling may provide additional benefits by improving cardiovascular fitness, muscular endurance, joint mobility, and patient confidence. This integrated approach addresses not only symptom relief but also functional independence and overall quality of life, outcomes that are increasingly recognized as priorities in patient-centered rehabilitation. Consequently, physiotherapists should consider combining aerobic and therapeutic exercises when designing individualized treatment programs for older adults with knee osteoarthritis.

Another clinically relevant observation is the excellent completion rate achieved in the present

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study, with all enrolled participants completing the six-week intervention. This finding suggests that the combined rehabilitation program was feasible and well tolerated by elderly individuals with mild-to-moderate knee osteoarthritis. High adherence is particularly important because the effectiveness of exercise therapy depends largely on consistent participation. The supervised nature of the program likely contributed to participant motivation, appropriate progression of exercise intensity, and timely correction of exercise technique, all of which may have enhanced treatment effectiveness. These findings further support the value of supervised physiotherapy in promoting adherence and optimizing rehabilitation outcomes.

Strengths of the Study

The present study has several strengths that enhance the clinical relevance of its findings. First, it evaluated multiple dimensions of patient health using the validated Knee Injury and Osteoarthritis Outcome Score (KOOS), allowing comprehensive assessment of pain, symptoms, functional status, and knee-related quality of life rather than relying on a single clinical outcome. Second, the intervention combined stationary cycling with therapeutic exercises, reflecting contemporary physiotherapy practice and providing an intervention that is readily applicable in routine rehabilitation settings. Third, all participants completed the intervention and post-treatment assessment, eliminating loss to follow-up and minimizing the potential for attrition bias. Finally, the study focused specifically on elderly individuals with early-stage knee osteoarthritis, a population in whom timely conservative management may delay disease progression and preserve long-term functional independence.

Limitations

Despite these encouraging findings, several limitations should be acknowledged when interpreting the results. First, the study employed a quasi-experimental pre–post design without a control group, limiting the ability to attribute the observed improvements exclusively to the intervention. Improvements may have been influenced, at least in part, by natural variation in symptoms, participant expectations, or other uncontrolled factors. Second, the relatively small sample recruited from two physiotherapy centers may limit the generalizability of the findings to other clinical settings or populations. Third, the intervention period was limited to six weeks, and no long-term follow-up was performed to determine whether the observed improvements were maintained over time. Fourth, outcomes were assessed using a patient-reported questionnaire, which may be influenced by reporting bias despite the strong validity and reliability of the KOOS instrument. Finally, objective performance-based measures such as quadriceps strength, gait speed, balance assessments, or the six-minute walk test were not included. Incorporating these measures could have provided a more comprehensive evaluation of functional recovery and treatment effectiveness.

Future Research

Future research should build upon the findings of the present study by conducting adequately powered randomized controlled trials comparing combined stationary cycling and therapeutic exercises with other evidence-based rehabilitation interventions. Longer follow-up periods are required to evaluate the sustainability of treatment effects and long-term adherence to exercise programs. Future studies should also incorporate objective biomechanical and performance-based outcome measures alongside patient-reported assessments to provide a more comprehensive understanding of rehabilitation effectiveness. In addition, investigating different exercise intensities, treatment durations, and progression strategies may help optimize rehabilitation protocols for individuals with varying stages of knee osteoarthritis. Evaluating the cost-effectiveness of combined exercise programs and their implementation in community-based and primary healthcare settings would further strengthen the evidence supporting widespread clinical adoption.

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Conclusion

In conclusion, the present study demonstrates that a supervised rehabilitation program combining stationary cycling with therapeutic exercises produces meaningful improvements in pain, symptoms, physical function, and knee-related quality of life among elderly individuals with knee osteoarthritis. The findings support current evidence that exercise-based rehabilitation should remain the foundation of conservative management while highlighting the additional benefits of integrating low-impact aerobic exercise with structured therapeutic exercises. By addressing multiple impairments simultaneously, this combined approach offers a practical, accessible, and clinically effective strategy for improving functional independence and enhancing health-related quality of life in older adults with knee osteoarthritis.

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