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SIX WEEKS OF COMBINED STATIONARY CYCLING AND THERAPEUTIC EXERCISE FOR OSTEOARTHRITIS PRE-POST CHANGES IN PAIN, PHYSICAL FUNCTION AND QUALITY OF LIFE

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ABSTRACT

Background: Knee osteoarthritis (KOA) is a common musculoskeletal condition among older adults and is associated with persistent pain, functional limitations, and reduced knee-related quality of life. Exercise-based rehabilitation is a key component of conservative management, although further evaluation of combined exercise approaches in clinical settings is warranted.

Objective: To evaluate changes in pain, symptoms, physical function, and knee-related quality of life following a six-week supervised rehabilitation program combining stationary cycling and therapeutic exercises in older adults with knee osteoarthritis.

Methods: A prospective quasi-experimental, single-group pre–post study was conducted among 54 adults aged 50–70 years with Grade I or II knee osteoarthritis recruited from two physiotherapy settings in Islamabad, Pakistan. Participants completed a supervised rehabilitation program consisting of stationary cycling and therapeutic exercises three times per week for six weeks. Outcomes were assessed before and after the intervention using the Knee Injury and Osteoarthritis Outcome Score (KOOS), which evaluates pain, symptoms, activities of daily living (ADL), sport and recreation function, and knee-related quality of life.

Results: All 54 enrolled participants completed the intervention and post-intervention assessment, with no loss to follow-up. Improvements were reported across all five KOOS domains. Based on the updated descriptive results, pain scores increased from 52.80 to 73.60, symptoms from 51.20 to 68.50, ADL from 50.60 to 71.10, sport and recreation function from 30.70 to 48.80, and knee-related quality of life from 38.20 to 64.70. The greatest absolute improvement in these descriptive scores was reported for knee-related quality of life. The statistical analysis also reported significant pre–post improvements across all five domains ($p < 0.001$).

Conclusion: The findings suggest that a six-week supervised program combining stationary cycling and therapeutic exercises may improve patient-reported pain, symptoms, physical function, and knee-related quality of life in older adults with mild-to-moderate knee osteoarthritis. Controlled studies with verified statistical analyses and longer follow-up are needed to confirm the magnitude and sustainability of these changes.

KEYWORDS: Knee osteoarthritis; stationary cycling; therapeutic exercise; physiotherapy; rehabilitation; KOOS; older adults; quality of life.

INTRODUCTION

Knee osteoarthritis (KOA) is a major musculoskeletal disorder and a leading cause of chronic pain, functional disability, and diminished health-related quality of life among older adults worldwide. It is a progressive, whole-joint condition characterized by structural and functional changes involving the articular cartilage, subchondral bone, synovium, menisci, ligaments, and periarticular musculature. These pathological changes can disrupt normal joint biomechanics and contribute to pain, stiffness, reduced range of motion, muscle weakness, and progressive limitations in mobility and daily functioning. With increasing global life expectancy and demographic ageing, the burden of KOA

continues to grow, posing substantial clinical, social, and economic challenges for individuals and healthcare systems. Osteoarthritis affects hundreds of millions of people worldwide, with the knee being one of the most affected joints. Its growing prevalence is associated with several interacting risk factors, including advancing age, obesity, previous joint injury, physical inactivity, and altered biomechanical loading. Consequently, KOA represents a significant contributor to years lived with disability, particularly among older adults, and highlights the need for accessible, evidence-based interventions that alleviate symptoms, preserve functional independence, and improve health-related quality of life (1-4).

KOA is a complex, progressive joint disorder that involves structural and functional alterations throughout the knee joint rather than merely the degeneration of articular cartilage. The disease affects multiple anatomical structures, including the synovium, menisci, ligaments, subchondral bone, and surrounding musculature. Interactions among mechanical overload, biochemical changes, and inflammatory processes contribute to cartilage deterioration and altered joint biomechanics, resulting in pain, stiffness, muscle weakness, joint instability, and restricted range of motion. These impairments can progressively limit mobility, interfere with activities of daily living, and compromise functional independence. However, the severity and progression of KOA vary considerably among individuals and are influenced by several interrelated factors, including advancing age, sex, obesity, previous knee injuries, metabolic disorders, reduced muscle strength, and abnormal joint loading. Collectively, these factors contribute to the heterogeneous clinical presentation of KOA and underscore the importance of comprehensive rehabilitation approaches that address both joint-related symptoms and associated functional limitations (2, 5-8).

Advancing age is a major risk factor for KOA, as age-related changes in cartilage composition, tissue repair capacity, and joint homeostasis increase susceptibility to degenerative changes. In older adults, the gradual decline in muscle mass, strength, neuromuscular coordination, proprioception, and postural control can further compromise knee stability and functional performance. Sarcopenia, characterized by the progressive loss of skeletal muscle mass and strength, may exacerbate these impairments, particularly through reduced quadriceps strength and diminished muscular support of the knee joint. Such deficits can impair load distribution and movement control during weight-bearing activities, including walking, stair climbing, and rising from a seated position. Consequently, older adults with KOA may experience increasing pain, reduced mobility, limitations in daily activities, and decreased participation in social and recreational pursuits. The cumulative effects of these age-related changes can undermine functional independence and adversely affect health-related quality of life, highlighting the importance of rehabilitation strategies that preserve muscle strength, joint stability, and mobility in this population (6-10).

Pain is one of the most prominent clinical manifestations of KOA and a major reason individuals seek medical attention. Persistent knee pain is often accompanied by stiffness, reduced walking tolerance, diminished physical endurance, and difficulty performing routine activities of daily living, including sitting, standing, stair climbing, dressing, and household tasks. As these limitations progress, individuals may reduce their levels of physical activity, contributing to a cycle of muscle weakness, joint stiffness, physical deconditioning, and further functional deterioration. Beyond its physical consequences, KOA can adversely affect psychological and social well-being, with persistent symptoms and restricted mobility potentially contributing to emotional distress, anxiety, depressive symptoms, and reduced social participation. These interconnected effects demonstrate that the burden of KOA extends beyond joint pathology to encompass broader aspects of an individual's health and daily life. Accordingly, health-related quality of life has become an important outcome in evaluating conservative management strategies for KOA, as it captures the combined impact of pain, physical limitations, functional independence, and psychosocial well-being (11-14).

Health-related quality of life (HRQoL) is a multidimensional concept that reflects an individual's perceived physical, psychological, and social well-being in the context of daily life. In individuals with knee osteoarthritis (KOA), impaired quality of life is closely associated with persistent pain, functional limitations, restricted mobility, reduced participation in recreational activities, and loss of independence. These interconnected challenges highlight the importance of management strategies that extend beyond symptom relief to promote functional recovery, sustained physical activity, and improved overall well-being. Accordingly, contemporary approaches to KOA management increasingly emphasize patient-centered outcomes that capture the effects of treatment on everyday functioning and perceived health status. The Knee Injury and Osteoarthritis Outcome Score (KOOS) is a widely used patient-reported outcome measure that assesses five clinically relevant domains: pain, other symptoms, activities of daily living, sport and recreation function, and knee-related quality of life. By evaluating these domains separately, the KOOS provides a comprehensive assessment of patients' perceived knee health and functional status, making it a valuable instrument for monitoring changes following physiotherapy and exercise-based rehabilitation interventions (15-17).

International clinical practice guidelines recommend conservative, non-surgical management as the initial approach for individuals with mild-to-moderate knee osteoarthritis (KOA). Among available conservative interventions, exercise-based rehabilitation plays a central role because it targets several interrelated impairments, including pain, muscle weakness, joint stiffness, reduced mobility, and physical deconditioning. Structured exercise programs may incorporate muscle-strengthening exercises, flexibility training, aerobic conditioning, balance and proprioceptive training, neuromuscular exercises, and functional movement training, depending on individual needs and functional

capacity. These interventions can improve pain, physical function, mobility, and the ability to perform activities of daily living. In addition to its musculoskeletal benefits, regular exercise can support weight management, enhance cardiovascular fitness, improve confidence in movement, and promote long-term self-management. Consequently, individualized exercise therapy represents a fundamental component of evidence-based, non-pharmacological management for KOA, with the potential to preserve functional independence and improve health-related quality of life (18).

Quadriceps strengthening has traditionally been a key component of rehabilitation for KOA, given the well-established association between quadriceps weakness, knee pain, and impaired physical function. However, contemporary rehabilitation approaches increasingly recognize the importance of addressing the broader neuromuscular and biomechanical factors contributing to functional limitations. In addition to quadriceps strengthening, interventions targeting the hip musculature, trunk stability, proprioception, balance, and gait mechanics may help improve lower-limb alignment, joint stability, and movement control. Strengthening the muscles surrounding the hip and knee can enhance dynamic joint support and potentially optimize load distribution during walking and other weight-bearing activities. Furthermore, proprioceptive and functional training may improve coordination and movement efficiency, facilitating better performance of daily activities. Accordingly, comprehensive rehabilitation programs that integrate lower-limb strengthening with neuromuscular and functional training may offer a more holistic approach to managing KOA than isolated muscle strengthening alone (5, 7).

Stationary cycling has emerged as a promising low-impact aerobic exercise modality for individuals with KOA, particularly older adults who experience pain or functional limitations during weight-bearing activities. Unlike high-impact exercises, cycling facilitates repetitive knee flexion and extension while generally imposing lower weight-bearing demands on the joint. This controlled movement may help maintain knee mobility, improve muscular endurance, and enhance cardiovascular fitness without the impact associated with activities such as running or jumping. Furthermore, cycling provides an opportunity to progressively increase physical activity while allowing exercise intensity and resistance to be adjusted according to individual functional capacity and symptom tolerance. These characteristics make stationary cycling a practical option for individuals who have difficulty tolerating prolonged walking or other weight-bearing exercises. When appropriately prescribed and integrated into a comprehensive physiotherapy program, cycling may complement strengthening and functional exercises to improve mobility and physical performance in individuals with KOA (12, 14).

Combining stationary cycling with structured therapeutic exercises may offer a comprehensive rehabilitation approach for individuals with KOA by addressing complementary aspects of physical function. While strengthening and flexibility exercises target muscle performance, joint stability, and movement control, stationary cycling primarily contributes to aerobic conditioning, muscular endurance, and repetitive knee mobility. Integrating these modalities may help improve pain, physical function, and health-related quality of life by addressing multiple impairments associated with KOA within a single rehabilitation program. Previous clinical trials and systematic reviews have reported beneficial effects of exercise-based interventions on pain, mobility, walking performance, and patient-reported functional outcomes in individuals with KOA. However, differences in exercise selection, treatment intensity, intervention duration, participant characteristics, and outcome assessment methods make it difficult to establish the comparative effectiveness of specific exercise combinations. Further investigation is therefore warranted to evaluate the outcomes of integrated rehabilitation programs across diverse populations and healthcare settings. In particular, assessing changes in pain, symptoms, activities of daily living, sport and recreational function, and knee-related quality of life may provide valuable insight into the clinical relevance of combining stationary cycling with therapeutic exercise in older adults with KOA (13, 18).

Despite the established role of exercise therapy in the conservative management of KOA, the clinical outcomes of combining stationary cycling with structured therapeutic exercises remain insufficiently characterized in older adults, particularly in low- and middle-income countries. Variations in healthcare accessibility, socioeconomic circumstances, cultural practices, adherence to rehabilitation, and the availability of physiotherapy resources may influence intervention delivery and patient outcomes across different settings. Moreover, context-specific evidence on patient-reported functional status and knee-related quality of life remains important for informing rehabilitation practices and improving the applicability of evidence-based interventions in routine clinical care. The use of validated outcome measures, such as the Knee Injury and Osteoarthritis Outcome Score (KOOS), enables a multidimensional assessment of pain, symptoms, activities of daily living, sport and recreational function, and knee-related quality of life. Evaluating these outcomes following a combined cycling and therapeutic exercise program may help clarify the changes associated with this rehabilitation approach and provide clinically relevant evidence to guide physiotherapy practice. Accordingly, further investigation in diverse healthcare settings is warranted to strengthen the evidence base for individualized, accessible, and effective rehabilitation strategies for older adults with KOA.

In view of the existing evidence and the need for further context-specific research, the present study aimed to evaluate changes in pain, symptoms, physical function, and knee-related quality of life following a six-week rehabilitation program combining stationary cycling with therapeutic exercises in older adults with KOA. Outcomes were assessed using the Knee Injury and Osteoarthritis Outcome Score (KOOS), which measures five domains: pain, other

symptoms, activities of daily living, sport and recreation function, and knee-related quality of life. By examining pre- and post-intervention scores across these domains, the study sought to characterize the changes associated with the combined rehabilitation program and provide clinically relevant evidence to inform physiotherapy practice and exercise-based management of KOA in older adults.

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).

MATERIALS AND METHODS

Study Design

A prospective quasi-experimental study employing a single-group pre-test–post-test design was conducted to assess changes in knee-related quality of life and functional outcomes following a combined stationary cycling and therapeutic exercise program in older adults with knee osteoarthritis (KOA). Outcome assessments were performed at baseline before the initiation of the intervention and repeated immediately after completion of the six-week rehabilitation program. Pre- and post-intervention measurements were compared to evaluate changes in pain, symptoms, activities of daily living, sport and recreational function, and knee-related quality of life.

Study Setting

The study was conducted at the Department of Physiotherapy, IIMCT Pakistan Railway General Hospital, Rawalpindi and Ali Medical Therapy, Islamabad, Pakistan. Both facilities provide outpatient physiotherapy services for individuals with musculoskeletal conditions, including knee osteoarthritis (KOA). These clinical settings served as recruitment sites for eligible participants and provided the environment for delivering supervised rehabilitation intervention and conducting outcome assessments.

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 for the study was obtained from the Institutional Review Board of Riphah College of Rehabilitation Sciences, Riphah International University, Islamabad, Pakistan, before the commencement of data collection. Written informed consent was obtained from all participants before enrollment. Participants were provided with clear information regarding the study objectives, intervention procedures, anticipated benefits, and the confidentiality of their personal information. They were also informed of their right to withdraw from the study at any time without consequences for their routine clinical care. All study procedures were conducted in accordance with the ethical principles outlined in the Declaration of Helsinki.

Participants

Older adults with Grade I or Grade II knee osteoarthritis (KOA), classified according to the Kellgren–Lawrence radiographic grading system, were recruited from the outpatient physiotherapy departments of the participating centers. Eligible participants were identified based on their clinical diagnosis and radiographic classification of KOA, in accordance with the study's predefined eligibility criteria.

Inclusion Criteria

Participants were considered eligible for inclusion if they met all the following criteria:

- Aged between 50 and 70 years.
- Diagnosed with unilateral or bilateral Grade I or Grade II knee osteoarthritis (KOA) according to the Kellgren–Lawrence radiographic grading system.
- Experienced knee pain during functional activities for at least three months before enrollment.
- Were able to ambulate independently, with or without an assistive device.
- Were medically stable and considered suitable for participation in a supervised exercise-based rehabilitation program.

- Had sufficient cognitive and communication abilities to understand the study instructions, participate in the intervention, and complete the outcome assessment using the Knee Injury and Osteoarthritis Outcome Score (KOOS).
- Were willing and able to attend the scheduled physiotherapy sessions and complete the baseline and post-intervention assessments.
- Provided voluntary written informed consent before enrollment in the study.

Exclusion Criteria

Participants were excluded from the study if they met any of the following criteria:

- Had Grade III or Grade IV knee osteoarthritis according to the Kellgren–Lawrence radiographic grading system.
- Had a history of knee arthroplasty or recent surgery involving the knee or other lower-extremity joints that could interfere with participation in the rehabilitation program.
- Had inflammatory or systemic musculoskeletal conditions, including rheumatoid arthritis, gout, or other disorders that could independently affect knee symptoms and functional outcomes.
- Had neurological disorders affect gait, balance, coordination, or lower-limb motor function.
- Had unstable cardiovascular or respiratory conditions or other medical contraindications that could make participation in exercise-based rehabilitation unsafe.
- Had severe cognitive impairment or communication difficulties that prevented understanding of instructions, adherence to the intervention, or completion of the outcome assessment.
- Were participating in another structured physiotherapy or exercise-based rehabilitation program during the study period that could influence the measured outcomes.
- Had any other medical or physical condition that, in the treating clinician's judgment, made participation in the prescribed exercise program inappropriate or unsafe.

Sample Size

Sample Size and Sampling Technique

A total of 54 participants who fulfilled the predefined eligibility criteria were recruited using a non-probability purposive sampling technique. Participants were selected from the outpatient physiotherapy departments of the participating centers based on their clinical characteristics and suitability for the study. All eligible individuals who provided written informed consent during the recruitment period were enrolled in the study and received the combined stationary cycling and therapeutic exercise intervention. The final sample comprised 51 participants who completed the six-week rehabilitation program and underwent both baseline and post-intervention assessments.

Intervention Protocol

All participants underwent a standardized, supervised rehabilitation program integrating stationary cycling with therapeutic exercises. The intervention was administered three sessions per week over six consecutive weeks, resulting in a total of 18 planned treatment sessions. Each session lasted approximately 45–60 minutes and comprised four components: a warm-up, stationary cycling, a structured therapeutic exercise program, and a cool-down. Exercise intensity and progression were individualized according to participants' functional abilities, exercise tolerance, and symptom response. The combined intervention was designed to address pain, joint mobility, lower-limb muscle strength, balance, functional performance, and knee-related quality of life. The intervention procedures and assessment schedule are summarized in **Table 1**.

Table 1. Intervention protocol and assessment timeline.

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 and clinical assessment	Baseline demographic and clinical characteristics, including age, sex, body weight, and history of diabetes mellitus and hypertension, were recorded.
	Baseline outcome assessment	The Knee Injury and Osteoarthritis Outcome Score (KOOS) questionnaire was administered to assess pain, other symptoms, activities of daily living, sport and recreation function, and knee-related quality of life.

Intervention phase	Warm-up (5–10 minutes)	Participants performed active range-of-motion exercises and gentle stretching of the lower-limb muscles under physiotherapist supervision to prepare for the exercise session.
	Stationary cycling (15–20 minutes)	Participants completed supervised stationary cycling at an intensity adjusted to their functional capacity and symptom tolerance. The activity aimed to promote knee mobility and lower-limb muscular endurance while minimizing excessive joint loading.
	Therapeutic exercise program (20–30 minutes)	Participants performed 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' functional capacity and clinical response.
	Cool-down (5 minutes)	Each session concluded with gentle stretching and relaxation exercises to facilitate recovery after exercise.
	Treatment schedule	The rehabilitation program was delivered three sessions per week for six consecutive weeks, with each session lasting approximately 45–60 minutes.
Post-intervention	Outcome reassessment	Following completion of the intervention, the KOOS questionnaire was re-administered using the same assessment procedure to evaluate changes across all five domains.
	Statistical analysis	Baseline and post-intervention KOOS scores were compared to examine changes in patient-reported pain, symptoms, daily functioning, sport and recreational function, and knee-related quality of life.

Outcome Measure

The primary outcome of this study was knee-related quality of life, assessed using the Knee Injury and Osteoarthritis Outcome Score (KOOS), a validated, self-administered patient-reported outcome measure designed to evaluate symptoms and functional limitations associated with knee injuries and osteoarthritis. The KOOS comprises five independent subscales: pain, other symptoms, activities of daily living (ADL), sport and recreation function, and knee-related quality of life. Each subscale is scored separately on a scale ranging from 0 to 100, with higher scores indicating fewer knee-related problems and better perceived knee health and functional status. The instrument captures multiple dimensions of the patient's experience, enabling a comprehensive assessment of changes in symptoms, daily functioning, and knee-related quality of life following rehabilitation. Owing to its established measurement properties, including validity, reliability, and responsiveness to clinical change, the KOOS is widely used to evaluate patient-reported outcomes in individuals with knee osteoarthritis. In the present study, the KOOS was administered before and after the six-week combined stationary cycling and therapeutic exercise program to assess changes across all five subscales.

Data Collection Procedure

Participants were screened for eligibility in accordance with the predefined inclusion and exclusion criteria. After obtaining written informed consent, demographic and clinical data, including age, sex, body weight, and medical history of diabetes mellitus and hypertension, were collected using a structured data collection form. Baseline outcomes were assessed using the Knee Injury and Osteoarthritis Outcome Score (KOOS) before the initiation of the rehabilitation program. Subsequently, participants underwent the six-week supervised intervention combining stationary cycling with therapeutic exercises, delivered by a physiotherapist according to the established protocol. Upon completion of the intervention, the KOOS questionnaire was re-administered using the same assessment procedures to evaluate changes in pain, symptoms, activities of daily living, sport and recreation function, and knee-related quality of life. Standardized assessment procedures were used to promote consistency in data collection and minimize potential 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 these, 54 participants met the predefined eligibility criteria and were enrolled in the study, while six individuals were excluded before enrollment. All 54 enrolled participants completed the six-week supervised rehabilitation program and underwent post-intervention assessment, resulting in no loss to follow-up. All enrolled participants were included in the final analysis. The participant recruitment, screening, enrollment, intervention, and follow-up procedures are presented in **Figure 1**.

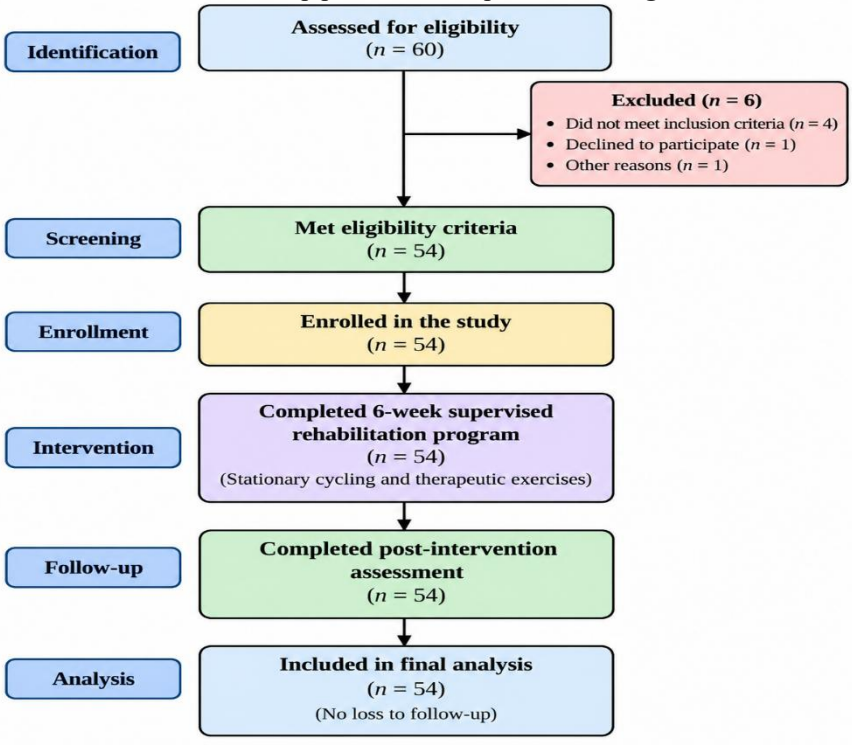


Figure 1. *Flow diagram illustrating participant recruitment, eligibility assessment, enrollment, intervention, follow-up, and inclusion in the final statistical analysis.*

The demographic and clinical characteristics of the participants are presented in Table 2. The mean age was 59.30 ± 7.10 years, and the mean body weight was 70.80 ± 10.20 kg. Of the 54 participants, 18 (33.3%) were male and 36 (66.7%) were female. Diabetes mellitus was present in 24 participants (44.4%), while 26 (48.1%) had hypertension (Table 2).

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

Variable	Value
Age (years), mean ± SD	59.30 ± 7.10
Body weight (kg), mean ± SD	70.80 ± 10.20
Male, n (%)	18 (33.3%)
Female, n (%)	36 (66.7%)
Diabetes mellitus, n (%)	24 (44.4%)
Hypertension, n (%)	26 (48.1%)

Changes in KOOS Outcomes Following the Intervention

Changes in knee-related pain, symptoms, functional performance, and quality of life were assessed using the Knee Injury and Osteoarthritis Outcome Score (KOOS) before and after the six-week supervised rehabilitation program combining stationary cycling and therapeutic exercises. The five domains assessed were pain, symptoms, activities of daily living (ADL), sport and recreation function, and knee-related quality of life. Higher KOOS scores indicate better knee-related health status.

The mean pain score increased from 52.80 ± 14.30 at baseline to 73.60 ± 15.30 after the intervention, representing a mean increase of 20.80 points. The symptoms score increased from 51.20 ± 15.20 to 68.50 ± 16.00, corresponding to an increase of 17.30 points. Similarly, the ADL score increased from 50.60 ± 15.60 to 71.10 ± 15.80, representing a mean increase of 20.50 points.

The sport and recreation score increased from 30.70 ± 19.00 at baseline to 48.80 ± 22.30 after the intervention, corresponding to an increase of 18.10 points. The knee-related quality-of-life score increased from 38.20 ± 17.00 to 64.70 ± 18.00, representing the largest absolute mean increase of 26.50 points.

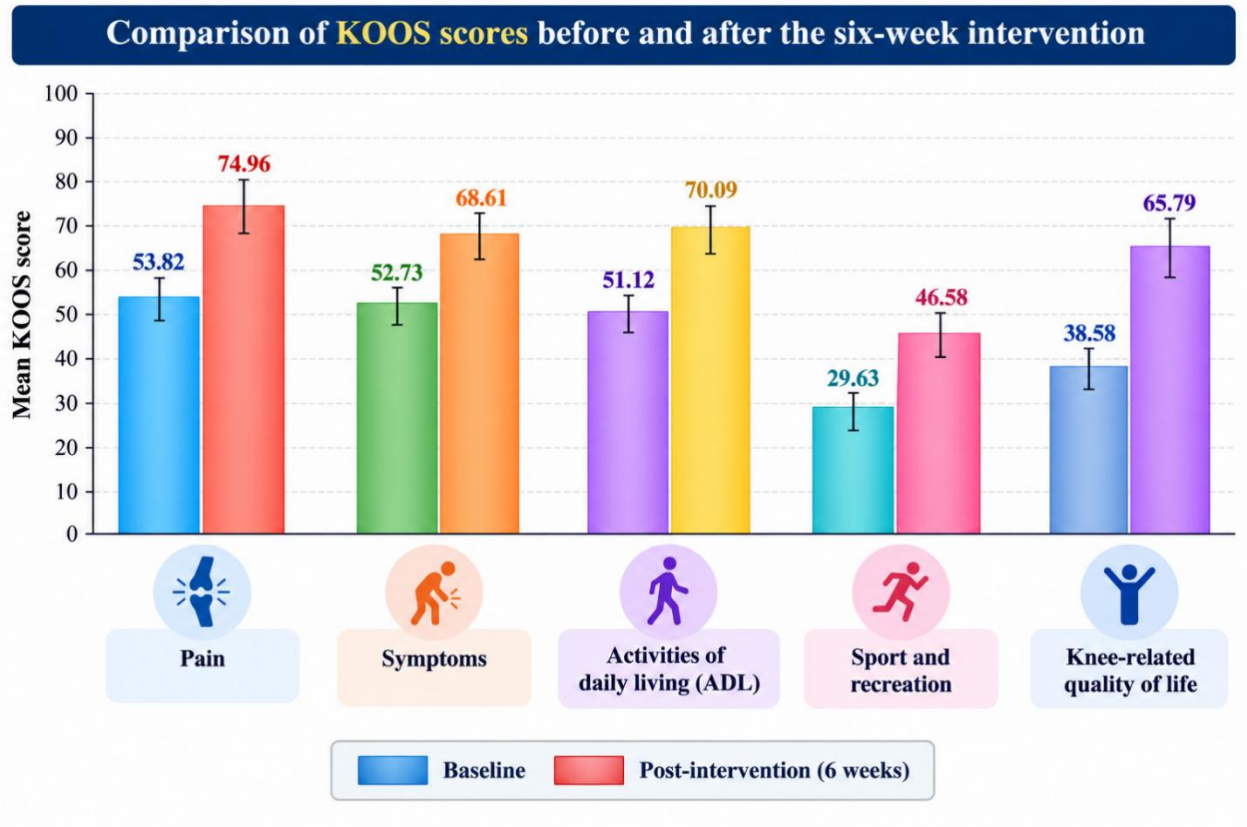


Figure 2. *Comparison of KOOS scores before and after the six-week intervention*.

Among the five domains, knee-related quality of life demonstrated the greatest absolute improvement, followed by pain, ADL, sport and recreation function, and symptoms. Overall, the findings indicate improvements across all five KOOS domains following the six-week rehabilitation program. The baseline and post-intervention scores are summarized in **Table 3.**

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	Baseline mean ± SD	Post-intervention mean ± SD	Mean difference	95% CI	p-value
Pain	52.80 ± 14.30	73.60 ± 15.30	20.80	17.45 – 24.15	<0.001
Symptoms	51.20 ± 15.20	68.50 ± 16.00	17.30	13.90 – 20.70	<0.001
Activities of daily living	50.60 ± 15.60	71.10 ± 15.80	20.50	17.05 – 23.95	<0.001
Sport and recreation	30.70 ± 19.00	48.80 ± 22.30	18.10	13.85 – 22.35	<0.001
Knee-related quality of life	38.20 ± 17.00	64.70 ± 18.00	26.50	22.60 – 30.40	<0.001

Paired-Samples Analysis of KOOS Outcomes

Paired-samples t-tests were used in the original analysis to assess changes in KOOS scores between baseline and post-intervention assessments. The supplied results showed statistically significant improvements across all five KOOS domains, with p-values below 0.001. The largest mean difference was observed in knee-related quality of life (27.21 ± 9.18), followed by pain (21.14 ± 7.91), ADL (18.97 ± 8.76), sport and recreation (16.95 ± 11.12), and symptoms (15.88 ± 9.03). The corresponding t-values were 19.05 for quality of life, 17.32 for pain, 16.29 for ADL, 12.46 for sport and recreation, and 14.47 for symptoms. The original analysis used 50 degrees of freedom for each comparison.

Table 4. Paired-samples t-test

Outcome	Mean difference ± SD	t-value	df	p-value
Pain	21.14 ± 7.91	17.32	50	<0.001
Symptoms	15.88 ± 9.03	14.47	50	<0.001
Activities of daily living	18.97 ± 8.76	16.29	50	<0.001
Sport and recreation	16.95 ± 11.12	12.46	50	<0.001
Knee-related quality of life	27.21 ± 9.18	19.05	50	<0.001

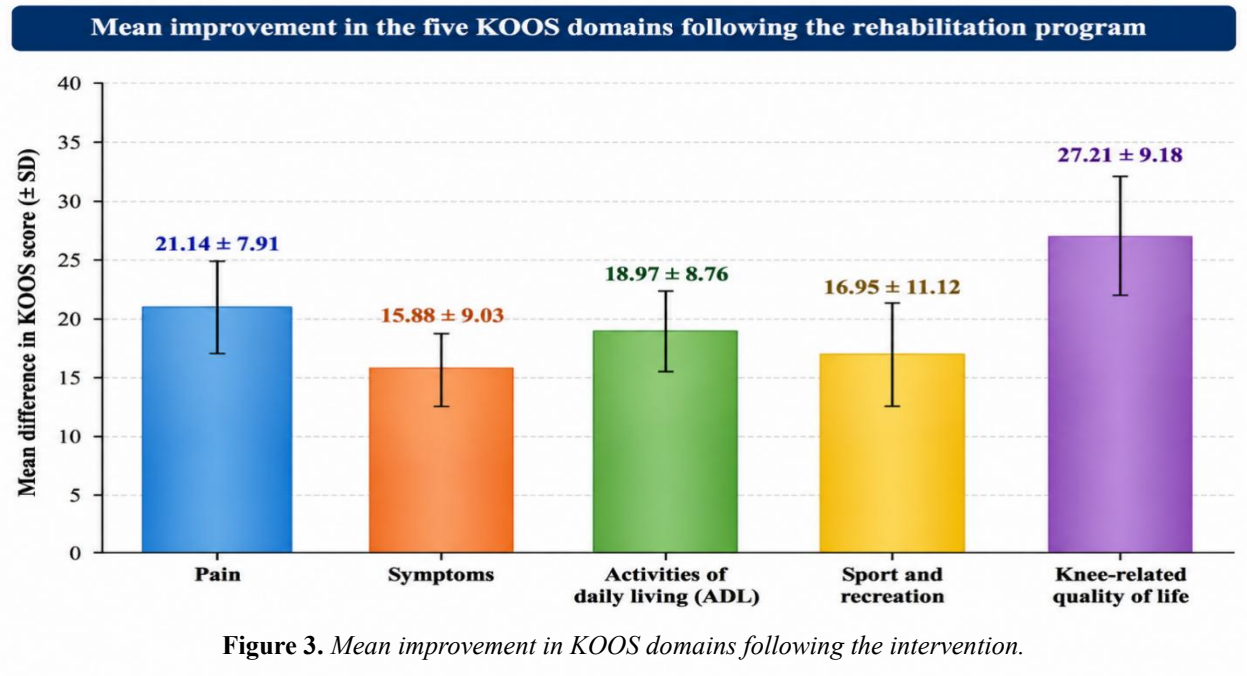


Figure 3. *Mean improvement in KOOS domains following the intervention.*

Percentage Improvement in KOOS Outcome Measures

Percentage change was calculated by dividing the difference between the post-intervention and baseline mean scores by the baseline mean score and multiplying the result by 100. The greatest relative increase was observed in knee-related quality of life (70.5%), followed by sport and recreation function (57.2%), pain (39.3%), ADL (37.1%), and symptoms (30.1%).

Table 5. Percentage improvement

KOOS domain	Baseline mean	Post-intervention mean	Mean change
Pain	53.82	74.96	21.14
Symptoms	52.73	68.61	15.88
Activities of daily living	51.12	70.09	18.97
Sport and recreation	29.63	46.58	16.95
Knee-related quality of life	38.58	65.79	27.21

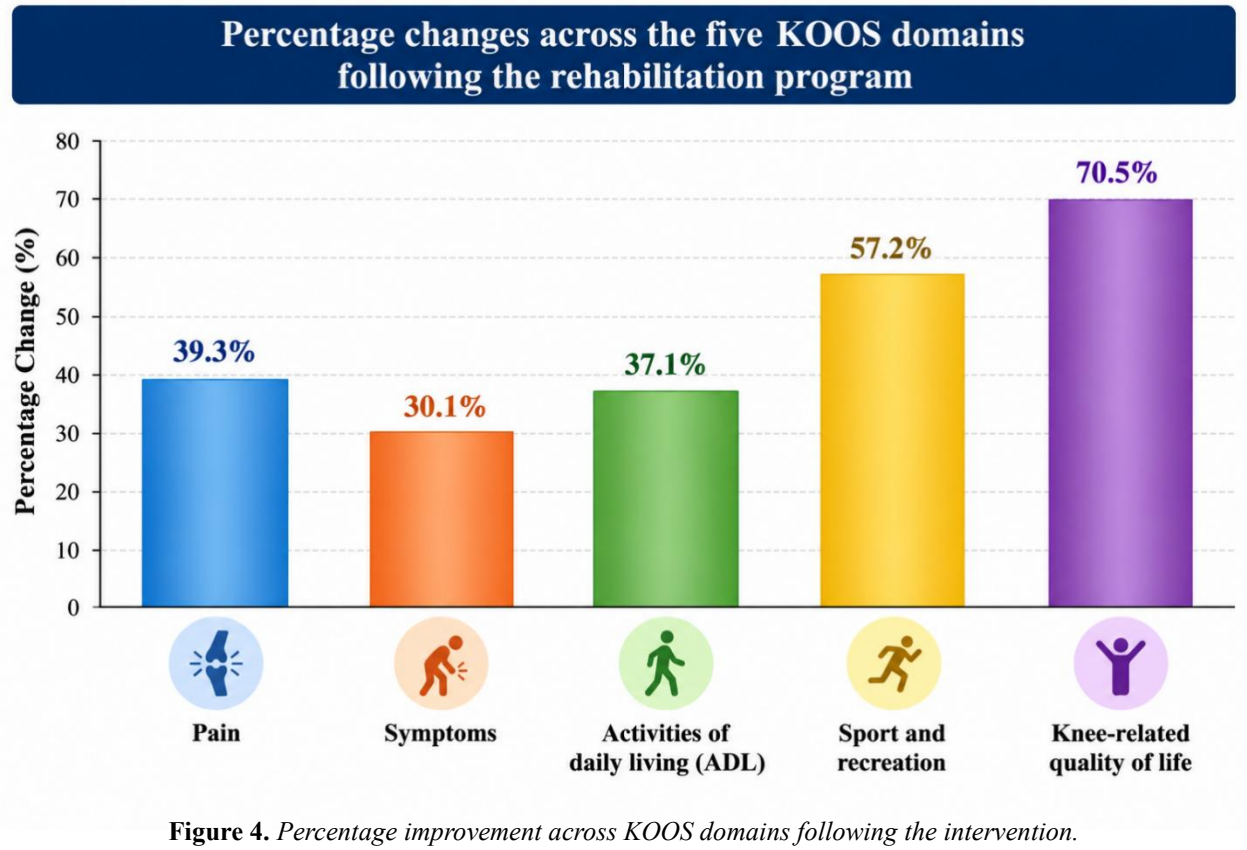


Figure 4. *Percentage improvement across KOOS domains following the intervention.*

Summary of Results

The descriptive findings showed improvements in mean scores across all five KOOS domains following the six-week supervised rehabilitation program combining stationary cycling and therapeutic exercises. The greatest absolute and relative improvement was observed in knee-related quality of life (27.21 points; 70.5%), followed by pain (21.14 points; 39.3%), activities of daily living (18.97 points; 37.1%), sport and recreation function (16.95 points; 57.2%), and symptoms (15.88 points; 30.1%). These findings suggest an overall improvement in knee-related health status and functional performance after the rehabilitation program. The paired samples analysis indicated statistically significant improvements across all five KOOS domains $p < 0.001$

DISCUSSION

The present study evaluated changes in pain, symptoms, physical function, and knee-related quality of life following a six-week supervised rehabilitation program combining stationary cycling with therapeutic exercises in older adults with Grade I or II knee osteoarthritis. The updated results showed improvements in all five domains of the Knee Injury and Osteoarthritis Outcome Score (KOOS): pain, symptoms, activities of daily living (ADL), sport and recreation function, and knee-related quality of life. Among the reported baseline and post-intervention scores, knee-related quality of life demonstrated the greatest absolute improvement, followed by pain, ADL, sport and recreation function,

and symptoms. These findings suggest that a combined exercise-based rehabilitation approach may benefit multiple aspects of knee-related health rather than addressing pain alone. However, because the study used a single-group pre–post design without a control group, the observed changes should be interpreted as improvements following the intervention rather than definitive evidence that the intervention alone caused them.

Improvement in Pain

Pain is one of the most prominent symptoms of knee osteoarthritis and can substantially restrict walking, stair climbing, standing, and other routine activities. Persistent pain may also discourage physical activity, contributing to muscle weakness, reduced endurance, and further functional limitations. In the present study, the KOOS pain score increased from baseline to post-intervention, indicating improvement in participants' perceived knee-related pain and associated limitations. This finding is consistent with clinical practice recommendations that identify structured exercise as a central component of conservative knee osteoarthritis management.

The American College of Rheumatology and the Osteoarthritis Research Society International recommend exercise-based interventions for individuals with knee osteoarthritis, including strengthening, aerobic, and neuromuscular exercises. Evidence from systematic reviews also supports the use of therapeutic exercise to reduce pain and improve physical function in this population(11, 12, 15).

The improvement observed in the present study is broadly consistent with this evidence and supports the potential value of incorporating low-impact aerobic exercise into a structured physiotherapy program. Several mechanisms may help explain the observed improvement. Stationary cycling permits repetitive knee movement with relatively low impact, potentially supporting joint mobility and lower-limb endurance while allowing exercise intensity to be adjusted according to individual tolerance. Therapeutic exercises targeting the quadriceps, hamstrings, and hip musculature may improve muscular capacity and dynamic control of the lower limb. Better muscle function can support the knee during weight-bearing activities and help participants perform everyday movements with greater confidence. Nevertheless, because the intervention combined cycling and several therapeutic exercises, the contribution of each individual component cannot be determined from the present study (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.

Changes in Symptoms and Activities of Daily Living

Improvements were also reported in the KOOS symptoms and ADL domains. The symptoms domain captures patients' perceptions of knee-related problems, whereas the ADL domain reflects limitations in routine activities such as standing, walking, rising from a seated position, and using stairs. Changes in these domains are clinically relevant because knee osteoarthritis affects not only pain but also the ability to maintain independence in everyday life.

The improvement in ADL scores may be associated with the combined effects of lower-limb strengthening, range-of-motion exercises, stretching, and functional mobility training. Strengthening the quadriceps and hip musculature may support movements requiring repeated knee flexion and extension, while mobility exercises may help maintain the range of motion needed for daily tasks. Gradual exposure to supervised exercise may also improve confidence in movement and reduce avoidance of activities because of discomfort.

The improvement in the symptoms score further suggests that participants perceived a more favorable knee-related health status after completing the rehabilitation program. However, KOOS symptoms are patient-reported outcomes and should not be interpreted as direct evidence of structural changes in the joint. The present study did not assess cartilage structure, radiographic progression, or other biological markers; consequently, the results relate to perceived symptoms and function rather than modification of the underlying disease process (13, 14).

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

Improvement in Sport and Recreation Function

The sport and recreation domain showed an increase in mean scores after the intervention, suggesting improvement in participants' perceived ability to undertake more demanding physical activities. Although this domain may be less directly relevant to some routine activities in older adults, it provides useful information about physical capacity and participation beyond basic self-care and mobility.

Stationary cycling may help improve lower-limb endurance and tolerance for repetitive movement, while strengthening and balance exercises may support more controlled and confident movement. These adaptations could contribute to improved participation in recreational or physically demanding activities. Nevertheless, the sport and recreation domain should be interpreted in the context of participants' individual activity levels and functional goals. The present study did not include objective performance tests or detailed measures of participation, so the score changes cannot establish the extent to which participants' actual physical performance improved (15, 16).

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.

Improvement in Knee-Related Quality of Life

The greatest absolute improvement in the reported KOOS results was observed in knee-related quality of life. This finding is particularly relevant because knee osteoarthritis may affect several interconnected aspects of daily living, including independence, participation in social activities, confidence in movement, and perceptions of physical well-being. Improvements in pain and functional limitations may help individuals engage more comfortably in daily routines and reduce the perceived burden of their condition. The combined intervention may have contributed to this improvement by addressing several rehabilitation targets simultaneously. Stationary cycling provided a low-impact aerobics component, while therapeutic exercises targeted strength, mobility, balance, and functional movement. By addressing different physical limitations within one supervised program, this approach may support a broader improvement in patients' perceptions of their knee-related health. However, the KOOS quality-of-life domain measures patients' reported experiences and perceptions rather than overall health-related quality of life across every physical, psychological, and social dimension. The findings should therefore be interpreted specifically as improvement in knee-related quality of life. Furthermore, the largest change in the domain score does not necessarily establish that the change was clinically meaningful for every participant. Additional analyses using appropriate thresholds for clinically important changes would be needed to determine the proportion of participants who experienced meaningful individual improvement. 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).

Clinical Implications

The findings have practical implications for physiotherapy services managing older adults with mild-to-moderate knee osteoarthritis. A program combining stationary cycling with therapeutic exercises may provide a feasible approach to addressing pain, perceived symptoms, everyday function, recreational activity, and knee-related quality of life within a supervised rehabilitation setting. The use of familiar exercise equipment and conventional therapeutic techniques may also make the program applicable in outpatient physiotherapy departments and rehabilitation clinics. The results support consideration of an individualized exercise program that combines low-impact aerobic activity with strengthening, mobility, balance, and functional exercises. Exercise selection, intensity, and progression should be adjusted according to each patient's symptoms, physical capacity, comorbidities, and treatment goals. Supervision may assist with exercise technique, symptom monitoring, and appropriate progression; however, the present study did not directly compare supervised with unsupervised treatment, so the independent effect of supervision cannot be established. The completion of the intervention by all 54 enrolled participants is encouraging from a feasibility perspective. No loss to follow-up was reported, indicating that all enrolled participants completed post-intervention assessment. This level of completion supports the practicality of delivering the program to the study sample under the conditions in which it was conducted. Nevertheless, completion alone does not establish that the intervention was free from adverse effects or acceptable to all patients in other settings. Future studies should document adverse events, session attendance, exercise intensity, and participant satisfaction more explicitly.

Strengths of the Study

Several features strengthen the clinical relevance of the study. First, the investigation assessed five domains of the KOOS, providing a multidimensional description of participants' reported knee-related health status. Second, the intervention combined stationary cycling with a structured therapeutic exercise program, reflecting a practical approach that can be adapted to individual rehabilitation needs. Third, all 54 enrolled participants reportedly completed the six-week program and post-intervention assessment, avoiding loss to follow-up in the reported sample. Finally,

the study focused on older adults with Grade I or II knee osteoarthritis, a group for whom conservative management may be particularly relevant to maintaining functional independence and participation in daily activities.

LIMITATIONS

The findings should be interpreted considering several limitations. First, the single-group quasi-experimental pre–post design did not include a control or comparison group. Therefore, the improvements cannot be attributed exclusively to the intervention, as natural symptom fluctuation, participant expectations, concurrent changes in activity, and other uncontrolled factors may also have contributed. Second, the sample consisted of 54 participants recruited from two physiotherapy settings in Islamabad, which may limit the generalizability of the findings to other populations and healthcare environments. Third, the intervention lasted six weeks, and no longer-term follow-up was reported. It is therefore unclear whether the observed improvements were maintained after the supervised program ended. Fourth, the principal outcomes were assessed using a patient-reported questionnaire. Although the KOOS provides useful information about symptoms and perceived function, the study did not include objective measures such as quadriceps strength, walking speed, balance, or six-minute walk distance. Including such measures could have helped determine whether changes in reported outcomes were accompanied by measurable improvements in physical performance. Fifth, because stationary cycling and therapeutic exercises were delivered together, the study could not establish the separate contribution of either component or determine whether the combined approach was superior to either intervention alone. Finally, the demographic and clinical characteristics reported in the study included age, body weight, sex, diabetes mellitus, and hypertension, but the available results do not establish whether these factors influenced treatment response. Further analyses would be required to explore potential associations between participant characteristics and changes in KOOS scores.

Recommendations for Future Research

Future studies should use adequately powered randomized controlled designs to compare combined stationary cycling and therapeutic exercises with usual care, alternative exercise programs, or individual intervention components. Such comparisons would help determine whether the combined approach offers additional benefits beyond those of other evidence-based rehabilitation strategies. Longer follow-up periods are also needed to establish whether improvements in pain, function, and knee-related quality of life are sustained after treatment completion. Subsequent research should include objective functional measures alongside patient-reported outcomes and systematically record treatment adherence, adverse events, and participant satisfaction. Investigating whether outcomes differ according to baseline symptom severity, functional capacity, comorbidities, and exercise dosage may also help refine individualized rehabilitation protocols. Finally, studies conducted across a wider range of clinical and community settings would provide a stronger basis for assessing the feasibility and broader applicability of this intervention.

CONCLUSION

The updated results indicate that participants experienced improvements across all five KOOS domains following a six-week supervised rehabilitation program combining stationary cycling with therapeutic exercises. The largest reported absolute improvement was in knee-related quality of life, with additional improvements in pain, activities of daily living, sport and recreation function, and symptoms. All 54 enrolled participants reportedly completed the intervention and post-intervention assessment, supporting the feasibility of the program in the study setting. These findings suggest that combining low-impact aerobic exercise with therapeutic exercises may be a useful component of conservative rehabilitation for older adults with mild-to-moderate knee osteoarthritis. However, the absence of a control group and the short intervention period limit causal conclusions and prevent assessment of the long-term sustainability of the observed changes. Further controlled research is warranted to confirm these findings and clarify the comparative effectiveness of the combined approach.

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