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Original Article

Baseline Predictors of Functional Recovery After a 12-Week Physiotherapy Rehabilitation Program in Patients With Grade II Knee Osteoarthritis: A Secondary Analysis of Trial Data

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ABSTRACT

Background: Functional recovery after rehabilitation for Grade II knee osteoarthritis varies across patients, even when similar physiotherapy protocols are used. Identifying recovery patterns across pain, stiffness, function, and knee mobility may help clinicians interpret treatment response beyond simple group comparison. **Objective:** To examine 12-week recovery gradients in patients with Grade II knee osteoarthritis receiving physiotherapy-based rehabilitation and to establish a secondary-analysis framework for evaluating baseline predictors of functional recovery. **Methods:** This secondary analysis used data from a single-blinded randomized clinical trial including 84 participants aged 40–60 years with Grade II knee osteoarthritis. Participants received either a Macquarie Injury Management Group protocol with conventional physiotherapy or a targeted knee exercise program with conventional physiotherapy. Outcomes were assessed at baseline, 8 weeks, and 12 weeks using the Numeric Pain Rating Scale, WOMAC pain, WOMAC stiffness, WOMAC physical function, and goniometric knee flexion and extension. Recovery gradients were calculated from baseline to 12 weeks using available aggregate data. **Results:** Pain improved by 3.93 points in the MMG protocol group and 4.40 points in the targeted knee exercise group. WOMAC pain improved by 7.62 and 9.69 points, WOMAC stiffness by 3.62 and 4.76 points, and WOMAC function by 21.40 and 19.81 points, respectively. Knee extension gain was 5.17° in the MMG protocol group and 10.14° in the targeted exercise group, while knee flexion gain was 17.95° and 23.19°, respectively. **Conclusion:** Both rehabilitation approaches produced meaningful 12-week improvement, with stronger symptom and mobility gradients observed after targeted knee exercise. Participant-level modelling is required to confirm independent baseline predictors of recovery.
Keywords: Knee osteoarthritis; rehabilitation; physiotherapy; WOMAC; pain; range of motion; secondary analysis.

INTRODUCTION

Knee osteoarthritis is a chronic musculoskeletal disorder in which pain, joint stiffness, restricted mobility, and progressive functional limitation interact to reduce independence and quality of life. Although radiographic degeneration provides an important diagnostic framework, the clinical burden of knee osteoarthritis is not determined by joint structure alone. Patients with similar radiographic

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grades may present with different levels of pain intensity, walking limitation, quadriceps inhibition, range-of-motion loss, and activity restriction, indicating that symptomatic and functional recovery is influenced by both biological and rehabilitation-related factors (1). This variability is particularly relevant in Grade II knee osteoarthritis, where structural change is usually mild to moderate and conservative rehabilitation remains a central component of management before disease progression produces more severe disability (2).

Exercise-based rehabilitation is consistently recommended for knee osteoarthritis because it addresses modifiable impairments such as muscle weakness, impaired neuromuscular control, reduced proprioception, joint stiffness, and fear-related activity avoidance (3,4). Strengthening and functional training may improve knee loading mechanics by enhancing quadriceps, hamstring, hip abductor, and dynamic stabilizer performance, while manual and soft-tissue approaches may contribute to short-term pain modulation and mobility improvement through changes in periarticular tissue extensibility and symptom sensitivity (5,6). However, clinical response to physiotherapy is not uniform. Some patients demonstrate marked improvement in pain and function after a structured program, whereas others show modest or incomplete recovery despite receiving comparable treatment exposure. This heterogeneity suggests that the question is not only whether rehabilitation works, but also which baseline characteristics help identify patients who are more likely to recover meaningfully.

Previous evidence has shown that exercise therapy can reduce pain and improve physical function in knee osteoarthritis, yet the magnitude of benefit may depend on patient-level characteristics, baseline symptom severity, mechanical loading, adherence capacity, and the chronicity of symptoms (7). Higher body mass index may increase compressive loading across the tibiofemoral joint and contribute to persistent symptoms, while longer symptom duration may reflect more established neuromuscular adaptation, reduced activity tolerance, and lower responsiveness to short-term rehabilitation. Similarly, baseline pain and baseline functional limitation may operate in two different ways: patients with worse baseline scores may have greater potential for absolute improvement, but they may also represent a subgroup with more complex disability and slower recovery. These competing possibilities make baseline predictor analysis clinically important, particularly when rehabilitation resources are limited and treatment planning must be individualized.

The Western Ontario and McMaster Universities Osteoarthritis Index is widely used to quantify pain, stiffness, and physical function in knee osteoarthritis, while the Numeric Pain Rating Scale and goniometric range-of-motion assessment provide complementary information on symptom intensity and joint mobility (8,9). When these outcomes are assessed repeatedly during rehabilitation, they allow change to be examined not only as a group-level treatment effect but also as an individual recovery pattern. This distinction is essential because a statistically significant mean improvement may obscure clinically meaningful differences between responders and non-responders. A secondary analysis focused on predictors of functional recovery can therefore add value beyond a primary trial report by identifying whether demographic factors, baseline impairment severity, symptom duration, affected side, body mass index, and treatment allocation are associated with 12-week improvement.

The original trial from which the present dataset was derived compared two physiotherapy-based rehabilitation approaches in adults aged 40–60 years with Grade II knee osteoarthritis. Participants received either a Macquarie Injury Management Group protocol with conventional physiotherapy or a targeted knee exercise program with conventional physiotherapy, and outcomes were measured at baseline, 8 weeks, and 12 weeks using pain, WOMAC domains, and knee range-of-motion measures. The primary trial question addressed comparative effectiveness between the two rehabilitation approaches. However, the available repeated-measures dataset also permits a distinct secondary question: whether baseline demographic and clinical characteristics can predict the degree of functional recovery after rehabilitation. This secondary focus is important because it shifts the interpretation from treatment superiority alone toward clinical decision-making, prognosis, and patient stratification.

Despite the growing evidence supporting exercise and physiotherapy for knee osteoarthritis, fewer clinical studies from rehabilitation settings have examined which routinely available baseline variables are associated with better recovery over a defined treatment period. This gap is relevant for daily practice because clinicians commonly record age, sex, body mass index, affected side, symptom duration, pain intensity, WOMAC scores, and range of motion before treatment begins, yet these measures are often reported descriptively rather than used to explain outcome variability. If such variables are associated with improvement, they could help clinicians identify patients requiring more intensive supervision, longer rehabilitation, weight-management referral, adherence support, or earlier reassessment of treatment response.

Therefore, the present study was designed as a secondary analysis of randomized trial data to evaluate baseline predictors of functional recovery after a 12-week physiotherapy rehabilitation program in patients with Grade II knee osteoarthritis. The population of interest was adults with clinically diagnosed Grade II knee osteoarthritis; the predictors of interest were baseline demographic and clinical factors, including age, sex, body mass index, symptom duration, affected side, baseline pain, baseline WOMAC scores, baseline knee flexion and extension, and rehabilitation allocation; the comparison was between different levels or categories of these predictors; and the primary outcome was improvement in WOMAC physical function at 12 weeks, with secondary outcomes including pain reduction, WOMAC pain and stiffness improvement, and range-of-motion gain. The study objective was to determine whether baseline clinical and demographic characteristics are associated with functional recovery following 12 weeks of physiotherapy-based rehabilitation in patients with Grade II knee osteoarthritis.

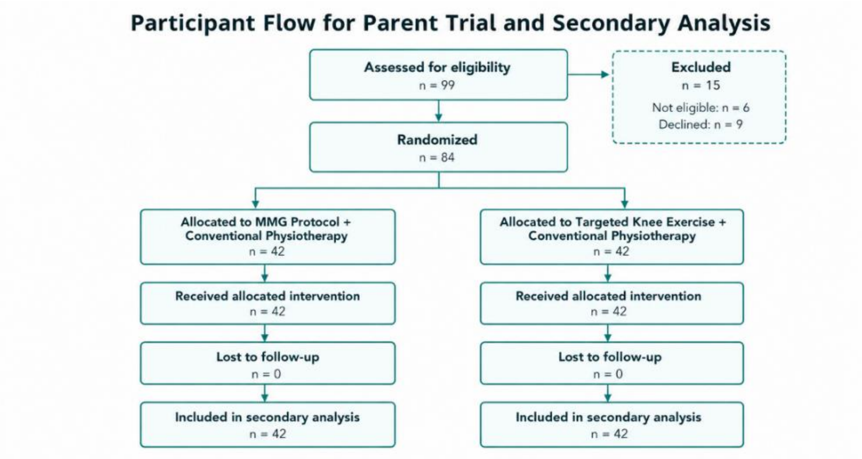
MATERIAL AND METHODS

This study was conducted as a secondary analysis of data obtained from a single-blinded randomized clinical trial evaluating physiotherapy-based rehabilitation outcomes in patients with Grade II knee osteoarthritis. The present analysis was not designed to re-estimate the comparative superiority of the original intervention arms; instead, it examined whether routinely recorded baseline demographic and clinical variables were associated with functional recovery after a 12-week rehabilitation period. The design and reporting approach were aligned with methodological principles for secondary analyses of clinical trial data and with randomized-trial reporting recommendations, with emphasis on transparent participant flow, prespecified outcome definitions, reproducible variable construction, and clear distinction between the parent trial question and the present prognostic objective (10).

The parent trial was conducted at Johar Pain Relief Center, Johar Town, Lahore, over a 9-month period after approval of the study synopsis and institutional ethical clearance. Adults were screened for eligibility before enrollment, and those meeting the selection criteria were invited to participate after explanation of the study procedures, expected rehabilitation schedule, voluntary participation, and confidentiality protections. Written informed consent was obtained before allocation and baseline assessment. Eligible participants were male and female patients aged 40–60 years with diagnosed Grade II knee osteoarthritis according to the Kellgren–Lawrence radiographic classification. Patients were excluded if they had undergone lower-extremity surgery, had active infection, previous lower-limb injury or surgery, post-traumatic knee stiffness, peripheral infectious disease, or secondary knee osteoarthritis. These eligibility criteria were used to create a clinically comparable sample of patients with mild radiographic knee osteoarthritis suitable for conservative rehabilitation assessment.

The original study enrolled 84 participants, with 42 participants assigned to the Macquarie Injury Management Group protocol plus conventional physiotherapy and 42 participants assigned to a targeted knee exercise program plus conventional physiotherapy. Participants were selected using purposive sampling from the clinical setting and were allocated to the two trial arms through a lottery-based randomization method. Outcome assessment was performed by a blinded assessor to reduce measurement expectation bias. For the present secondary analysis, all randomized participants with available baseline and follow-up outcome data were included according to the available-case principle. Because the parent dataset reported no attrition during intervention or follow-up, no imputation procedure was applied for missing outcome values. Data were reviewed for internal consistency before analysis, including verification of group coding, assessment time points, plausible value ranges for pain and WOMAC scores, and consistency of range-of-motion values across baseline, 8-week, and 12-week records.

Both rehabilitation arms received physiotherapy-based management across the intervention period. The Macquarie Injury Management Group protocol arm received a manual-therapy-oriented knee protocol emphasizing soft-tissue mobilization around the knee region in addition to conventional physiotherapy. Participants were positioned supine with the knee extended while the treating physiotherapist applied manual soft-tissue techniques to periarticular tissues for a brief standardized period, followed by conventional therapeutic exercise and physical therapy procedures. The targeted knee exercise arm received a structured exercise program designed to improve knee strength, proprioception, dynamic stability, and functional performance, in addition to conventional physiotherapy. The program incorporated progressive exercises for the quadriceps, hamstrings, hip abductors, and functional movement patterns, including exercises such as straight-leg raising, terminal knee extension, single-leg stability work, dynamic balance activities, sit-to-stand training, and step-up practice. Conventional physiotherapy included strengthening and stretching exercises for major lower-limb muscle groups, patellar mobilization, range-of-motion exercises, and pain-modulating electrotherapy. Sessions were delivered three times weekly during the intervention period, and outcomes were recorded at baseline, the 8th week, and the 12th week.



MMG, Macquarie Injury Management Group. The diagram summarizes trial screening, allocation, follow-up, and inclusion in the present secondary analysis.

The primary outcome for the present secondary analysis was functional recovery at 12 weeks, operationalized as improvement in the WOMAC physical function score from baseline to the 12-week assessment. The WOMAC index was used to quantify knee osteoarthritis-related pain, stiffness, and functional limitation, with higher scores reflecting greater symptom burden or disability. Secondary recovery outcomes included improvement in Numeric Pain Rating Scale score, improvement in WOMAC pain score, improvement in WOMAC stiffness score, gain in knee flexion range of motion, and gain in knee extension range of motion from baseline to 12 weeks. Pain intensity was measured using the Numeric Pain Rating Scale, with scores ranging from 0 to 10 and higher values indicating greater pain severity. Knee flexion and extension range of motion were measured with a universal goniometer and recorded in degrees. Baseline predictor variables included age in years, sex, body mass index, affected side, duration of symptoms, baseline pain intensity, baseline WOMAC pain, baseline WOMAC stiffness, baseline WOMAC physical function, baseline knee flexion, baseline knee extension, and rehabilitation allocation. Change scores were calculated so that positive values represented clinical improvement: pain and WOMAC improvement were calculated by subtracting 12-week scores from baseline scores, whereas range-of-motion gain was calculated by subtracting baseline degrees from 12-week degrees.

To support clinically interpretable analysis, functional recovery was examined both as a continuous improvement score and, where appropriate, as a categorical responder outcome. A participant was classified as a functional responder if the WOMAC physical function score improved by at least 30% from baseline to 12 weeks. Pain response was similarly defined as at least 30% improvement in Numeric Pain Rating Scale score from baseline to 12 weeks. These responder definitions were used to distinguish patients with clinically meaningful improvement from those with smaller numerical changes. The predictor framework followed a PICO-informed secondary-analysis structure: the population consisted of adults with Grade II knee osteoarthritis; the indicators were baseline demographic, clinical, and impairment-related variables; the comparisons were between predictor categories or across predictor gradients; and the outcomes were 12-week functional and symptomatic recovery measures.

Statistical analysis was performed using SPSS version 21. Continuous variables were examined for distributional properties using normality testing and inspection of central tendency and dispersion. Normally distributed continuous variables were summarized using mean and standard deviation, while skewed variables were summarized using median and interquartile range. Categorical variables were presented as frequencies and percentages. For bivariate analyses, independent-samples t tests or Mann–Whitney U tests were used for two-group comparisons according to distributional suitability, while chi-square or Fisher exact tests were used for categorical associations. Spearman correlation analysis was used to examine associations between baseline continuous predictors and 12-week change scores when non-normality was present. Within-participant changes across repeated assessments were assessed using non-parametric repeated-measures procedures when assumptions for parametric testing were not met. Between-group differences in recovery outcomes were considered descriptively in the predictor framework rather than treated as the sole inferential focus of the manuscript.

Multivariable modelling was planned to evaluate independent predictors of 12-week functional recovery. For continuous WOMAC physical function improvement, linear regression was used when model assumptions were acceptable; otherwise, robust or rank-based interpretation was preferred. For categorical responder analysis, binary logistic regression was used to estimate odds ratios with 95% confidence intervals for clinically meaningful recovery. Candidate predictors were selected according to clinical relevance and availability in the dataset, including age, sex, body mass index, symptom duration, baseline WOMAC physical function, baseline pain intensity, baseline knee flexion or extension, and rehabilitation allocation. To limit overfitting in the sample of 84 participants, the number of predictors entered into multivariable models was restricted, and highly correlated baseline variables were not entered simultaneously in the same model. Confounding was addressed by adjusting for rehabilitation allocation and baseline severity when examining associations between demographic or clinical variables and recovery outcomes. Statistical significance was set at $p \leq 0.05$, and interpretation emphasized effect size, direction of association, and confidence intervals rather than p-values alone.

Bias control was addressed at several levels. Selection bias was reduced in the parent trial by applying explicit eligibility criteria before allocation. Measurement bias was limited by blinded outcome assessment and use of standardized instruments for pain, function, and range of motion. Confounding was considered analytically by incorporating baseline severity and treatment allocation into multivariable models. Reporting bias was minimized in the present secondary analysis by defining recovery variables before interpretation and by distinguishing primary functional recovery from secondary symptomatic and mobility outcomes. Data integrity was supported through uniform coding of assessment time points, verification of score direction before change-score calculation, and cross-checking of derived variables against the original baseline and follow-up values. The study was conducted in accordance with ethical principles for human-subject research, including voluntary participation, written informed consent, confidentiality of participant information, and the right to withdraw without penalty.

RESULTS

A total of 84 participants with Grade II knee osteoarthritis were included in the secondary analysis, with 42 participants allocated to the Macquarie Injury Management Group protocol plus conventional physiotherapy and 42 participants allocated to targeted knee exercise plus conventional physiotherapy. All participants had baseline, 8-week, and 12-week outcome assessments available for the reported clinical outcomes.

Table 1. Baseline Continuous Characteristics of Participants by Rehabilitation Allocation

Variable	MMG Protocol Group, n	MMG Protocol Group, Mean ± SD	Targeted Knee Exercise Group, n	Targeted Knee Exercise Group, Mean ± SD
Age, years	42	51.69 ± 6.33	42	52.43 ± 6.29
Height, cm	42	160.40 ± 4.66	42	160.76 ± 4.86
Weight, kg	42	71.10 ± 8.42	42	70.12 ± 8.27
Body mass index, kg/m²	42	27.59 ± 3.29	42	27.10 ± 3.28

SD, standard deviation; MMG, Macquarie Injury Management Group.

The two rehabilitation groups were closely comparable for baseline continuous characteristics. Mean age differed by less than 1 year between the MMG protocol group and the targeted knee exercise group, with values of 51.69 ± 6.33 years and 52.43 ± 6.29 years, respectively. Mean body mass index was also similar across groups, measuring 27.59 ± 3.29 kg/m² in the MMG protocol group and 27.10 ± 3.28 kg/m² in the targeted knee exercise group, indicating that both cohorts were broadly similar in baseline anthropometric profile.

Table 2. Baseline Affected Side and Duration of Symptoms by Rehabilitation Allocation

Variable	Category	MMG Protocol Group, n (%)	Targeted Knee Exercise Group, n (%)
Affected side	Left	19 (45.24)	14 (33.33)
Affected side	Right	23 (54.76)	28 (66.67)
Duration of symptoms	Less than 6 months	13 (31.00)	18 (42.90)
Duration of symptoms	1 year	21 (50.00)	14 (33.30)
Duration of symptoms	2 years	6 (14.30)	8 (19.00)
Duration of symptoms	More than 2 years	2 (4.80)	2 (4.80)

MMG, Macquarie Injury Management Group.

Right-sided knee involvement was more frequent than left-sided involvement in both groups, affecting 23 participants (54.76%) in the MMG protocol group and 28 participants (66.67%) in the targeted knee exercise group. Symptom duration showed a different distribution across groups: the largest proportion of participants in the MMG protocol group reported symptoms for 1 year, whereas the largest proportion in the targeted knee exercise group reported symptoms for less than 6 months.

Table 3. Pain and WOMAC Outcome Trajectory From Baseline to 12 Weeks

Outcome	Group	Baseline, Mean ± SD	8 Weeks, Mean ± SD	12 Weeks, Mean ± SD	Baseline to 8-Week Change	Baseline to 12-Week Change	χ^2	p-value
NPRS	MMG Protocol	7.52 ± 2.18	6.45 ± 2.24	3.59 ± 2.04	1.07	3.93	83.036	<0.001
NPRS	Targeted Knee Exercise	6.52 ± 1.92	4.90 ± 1.82	2.12 ± 1.63	1.62	4.40	73.752	<0.001
WOMAC pain	MMG Protocol	11.52 ± 1.93	6.17 ± 1.36	3.90 ± 1.66	5.35	7.62	25.671	<0.001
WOMAC pain	Targeted Knee Exercise	12.02 ± 2.25	7.21 ± 1.55	2.33 ± 1.72	4.81	9.69	25.671	<0.001
WOMAC stiffness	MMG Protocol	5.43 ± 1.19	3.21 ± 1.20	1.81 ± 1.02	2.22	3.62	80.600	<0.001
WOMAC stiffness	Targeted Knee Exercise	5.57 ± 1.21	1.81 ± 0.99	0.81 ± 0.67	3.76	4.76	71.217	<0.001

Outcome	Group	Baseline, Mean ± SD	8 Weeks, Mean ± SD	12 Weeks, Mean ± SD	Baseline to 8-Week Change	Baseline to 12-Week Change	χ²	p-value
WOMAC function	MMG Protocol	34.02 ± 8.91	21.64 ± 6.30	12.62 ± 4.04	12.38	21.40	84.000	<0.001
WOMAC function	Targeted Knee Exercise	28.45 ± 11.57	15.17 ± 7.60	8.64 ± 5.09	13.28	19.81	84.000	<0.001

NPRS, Numeric Pain Rating Scale; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index; SD, standard deviation; MMG, Macquarie Injury Management Group. Change scores for NPRS and WOMAC outcomes were calculated as baseline score minus follow-up score. Friedman test was used for within-group repeated-measures comparisons.

Both rehabilitation allocations showed progressive reductions in pain and WOMAC scores over the 12-week period. NPRS decreased from 7.52 ± 2.18 to 3.59 ± 2.04 in the MMG protocol group and from 6.52 ± 1.92 to 2.12 ± 1.63 in the targeted knee exercise group. WOMAC function improved in both groups, with a baseline-to-12-week reduction of 21.40 points in the MMG protocol group and 19.81 points in the targeted knee exercise group. WOMAC stiffness showed a larger absolute 12-week reduction in the targeted knee exercise group, decreasing by 4.76 points compared with 3.62 points in the MMG protocol group. All within-group repeated-measures comparisons were statistically significant, with p-values below 0.001.

Table 4. Knee Range-of-Motion Trajectory From Baseline to 12 Weeks

Outcome	Group	Baseline, Mean ± SD	8 Weeks, Mean ± SD	12 Weeks, Mean ± SD	Baseline to 8-Week Gain	Baseline to 12-Week Gain	χ²	p-value
Knee extension, degrees	MMG Protocol	119.14 ± 2.23	120.10 ± 2.34	124.31 ± 2.69	0.96	5.17	25.671	<0.001
Knee extension, degrees	Targeted Knee Exercise	119.29 ± 2.33	126.36 ± 1.87	129.43 ± 1.82	7.07	10.14	25.671	<0.001
Knee flexion, degrees	MMG Protocol	110.26 ± 7.18	116.50 ± 1.99	128.21 ± 2.12	6.24	17.95	25.671	<0.001
Knee flexion, degrees	Targeted Knee Exercise	109.14 ± 8.71	118.83 ± 1.90	132.33 ± 2.07	9.69	23.19	25.671	<0.001

SD, standard deviation; MMG, Macquarie Injury Management Group. Gain scores were calculated as follow-up value minus baseline value. Friedman test was used for within-group repeated-measures comparisons.

Range-of-motion values increased in both rehabilitation groups across the 12-week follow-up. Knee extension improved by 5.17 degrees in the MMG protocol group and 10.14 degrees in the targeted knee exercise group. Knee flexion increased from 110.26 ± 7.18 degrees to 128.21 ± 2.12 degrees in the MMG protocol group and from 109.14 ± 8.71 degrees to 132.33 ± 2.07 degrees in the targeted knee exercise group. The largest absolute range-of-motion gain was observed for knee flexion in the targeted knee exercise group, with a 23.19-degree increase over 12 weeks.

Table 5. Between-Group Comparison of Pain, Range of Motion, and WOMAC Outcomes

Outcome	Time Point	MMG Protocol Group, Median (IQR)	Targeted Knee Exercise Group, Median (IQR)	Z	p-value
Pain	Baseline	8 (3)	7 (3)	-2.218	0.227
Pain	8 weeks	6 (3)	5 (2)	-3.264	0.001
Pain	12 weeks	4 (2)	2 (2)	-3.246	0.001
Knee extension	Baseline	119 (2)	119 (2)	-0.154	0.877
Knee extension	8 weeks	120 (2)	126 (2)	-7.531	0.001
Knee extension	12 weeks	124 (3)	129 (3)	-7.319	0.001
Knee flexion	Baseline	110 (10)	109 (12)	-0.280	0.780
Knee flexion	8 weeks	117 (3)	119 (3)	-4.646	0.001
Knee flexion	12 weeks	128 (3)	132 (4)	-6.598	0.001
WOMAC pain	Baseline	12 (3)	12 (4)	-1.112	0.266
WOMAC pain	8 weeks	6 (2)	7 (2)	-3.094	0.001
WOMAC pain	12 weeks	4 (2)	2 (2)	-4.085	0.001
WOMAC stiffness	Baseline	5 (2)	6 (1)	-0.574	0.566

Outcome	Time Point	MMG Protocol Group, Median (IQR)	Targeted Knee Exercise Group, Median (IQR)	Z	p-value
WOMAC stiffness	8 weeks	3 (2)	2 (2)	-4.830	0.001
WOMAC stiffness	12 weeks	2 (1)	1 (1)	-4.571	0.001
WOMAC function	Baseline	34 (12)	29 (14)	-2.357	0.118
WOMAC function	8 weeks	22 (8)	15 (10)	-3.690	0.001
WOMAC function	12 weeks	13 (6)	9 (7)	-3.764	0.001

IQR, interquartile range; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index; MMG, Macquarie Injury Management Group. Mann–Whitney U test was used for between-group comparisons.

Median baseline values were comparable between groups for pain, knee extension, knee flexion, WOMAC pain, WOMAC stiffness, and WOMAC function, with reported p-values greater than 0.05. At 8 weeks and 12 weeks, between-group differences were reported for all clinical outcomes. Median pain decreased to 4 (2) in the MMG protocol group and 2 (2) in the targeted knee exercise group at 12 weeks. Knee extension reached 124 (3) degrees in the MMG protocol group and 129 (3) degrees in the targeted knee exercise group at 12 weeks, while knee flexion reached 128 (3) degrees and 132 (4) degrees, respectively. WOMAC function at 12 weeks was 13 (6) in the MMG protocol group and 9 (7) in the targeted knee exercise group.

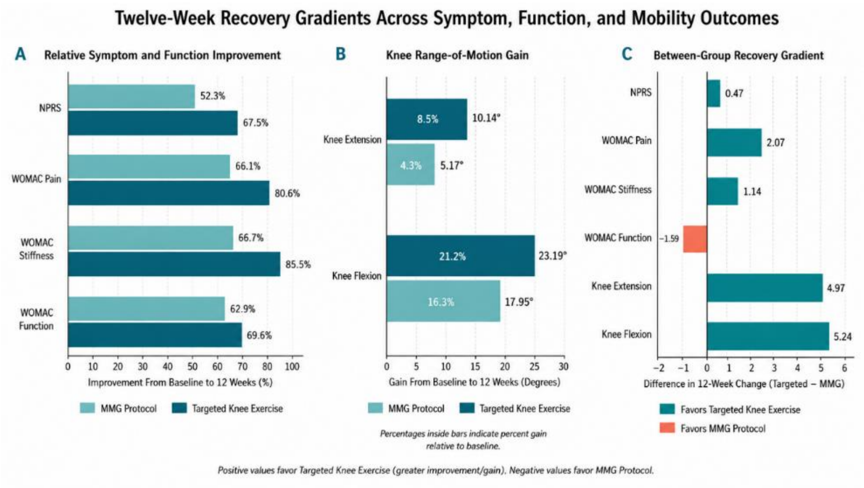
Table 6. Derived 12-Week Recovery Gradients for Primary and Secondary Outcomes

Outcome	MMG Protocol Group, Baseline to 12-Week Change	Targeted Knee Exercise Group, Baseline to 12-Week Change	Absolute Difference in Change
NPRS	3.93	4.40	0.47
WOMAC pain	7.62	9.69	2.07
WOMAC stiffness	3.62	4.76	1.14
WOMAC function	21.40	19.81	-1.59
Knee extension, degrees	5.17	10.14	4.97
Knee flexion, degrees	17.95	23.19	5.24

NPRS, Numeric Pain Rating Scale; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index; MMG, Macquarie Injury Management Group. Change scores for NPRS and WOMAC outcomes were calculated as baseline score minus 12-week score. Change scores for range-of-motion outcomes were calculated as 12-week value minus baseline value.

The derived 12-week recovery gradients showed larger absolute change in the targeted knee exercise group for NPRS, WOMAC pain, WOMAC stiffness, knee extension, and knee flexion. The largest between-group difference in change was observed for knee flexion, where the targeted knee exercise group gained 23.19 degrees compared with 17.95 degrees in the MMG protocol group, yielding a 5.24-degree difference in recovery gradient. Knee extension also showed a larger gain in the targeted knee exercise group, with an absolute difference in change of 4.97 degrees. WOMAC function showed substantial improvement in both groups, with a 21.40-point reduction in the MMG protocol group and a 19.81-point reduction in the targeted knee exercise group.

The aggregate results indicate measurable 12-week recovery across pain, stiffness, functional limitation, and knee mobility in both rehabilitation allocations. Because the present manuscript is designed as a secondary predictor analysis, participant-level data are required to complete the core inferential objective, including Spearman correlations between baseline variables and recovery scores, regression models for WOMAC functional recovery, and responder analyses based on clinically meaningful improvement thresholds. These analyses should be added once the raw dataset is available, because adjusted estimates, confidence intervals, and predictor-specific p-values cannot be validly derived from the aggregate tables alone.



The figure demonstrates a consistent 12-week recovery gradient across both rehabilitation groups, with the targeted knee exercise group showing larger relative improvement in most symptom and mobility outcomes. In Panel A, relative symptom and function improvement was greater with targeted exercise for NPRS (67.5% vs 52.3%), WOMAC pain (80.6% vs 66.1%), WOMAC stiffness (85.5% vs 66.7%), and WOMAC function (69.6% vs 62.9%). In Panel B, knee range-of-motion gains were also larger in the targeted exercise group, with knee extension increasing by 10.14° compared with 5.17° in the MMG protocol group, and knee flexion increasing by 23.19° compared with 17.95°. Panel C further highlights the between-group recovery gradient, showing the largest absolute advantages for targeted exercise in knee flexion (+5.24°) and knee extension (+4.97°), followed by WOMAC pain (+2.07), WOMAC stiffness (+1.14), and NPRS (+0.47), while WOMAC function showed substantial improvement in both groups with a small absolute advantage in change toward the MMG group (-1.59). Overall, the visual pattern indicates broader and steeper improvement with targeted knee exercise, particularly for mobility restoration and symptom reduction.

DISCUSSION

The present secondary analysis examined 12-week recovery patterns in patients with Grade II knee osteoarthritis who underwent physiotherapy-based rehabilitation. Rather than restating the primary comparative trial question, this analysis focused on the clinical meaning of baseline-to-follow-up recovery gradients across pain, stiffness, physical function, and knee mobility. The findings show that both rehabilitation approaches were associated with marked improvement over 12 weeks, but the pattern of recovery was not uniform across outcomes. Symptom-related measures and knee range of motion demonstrated larger relative or absolute recovery in the targeted knee exercise group for most domains, whereas WOMAC physical function improved substantially in both groups, with only a small difference in absolute change between the two rehabilitation approaches. This pattern suggests that functional recovery in Grade II knee osteoarthritis is multidimensional and should not be interpreted through a single endpoint alone.

The improvement in pain intensity across both rehabilitation allocations is consistent with the broader evidence that structured physiotherapy can reduce symptomatic burden in knee osteoarthritis. Exercise therapy may reduce pain through improved muscle force generation, enhanced neuromuscular control, reduced aberrant joint loading, and improved confidence in movement, while manual and soft-tissue components may contribute to short-term modulation of pain sensitivity and periarticular tissue mobility (11,12). In the present analysis, the Numeric Pain Rating Scale improved by 3.93 points in the MMG protocol group and 4.40 points in the targeted knee exercise group over 12 weeks. Although the difference in absolute pain change was modest, the relative improvement was larger in the targeted exercise group, indicating that progressive active rehabilitation may have provided a stronger symptom-reduction trajectory in this cohort. This interpretation is clinically plausible because knee osteoarthritis pain is closely linked to muscular inhibition, impaired movement confidence, and altered loading strategies, all of which are directly addressed by progressive strengthening and functional retraining (13).

The WOMAC domain findings provide a more detailed view of recovery than pain scores alone. WOMAC pain improved by 7.62 points in the MMG protocol group and 9.69 points in the targeted knee exercise group, while WOMAC stiffness improved by 3.62 and 4.76 points, respectively. These findings suggest that the targeted knee exercise program may have produced a broader effect on symptom behavior, particularly stiffness, which is clinically relevant because stiffness can restrict activity initiation and reduce adherence to walking, stair climbing, squatting, and sit-to-stand tasks. The greater stiffness reduction observed with targeted exercise may reflect repeated active joint movement, progressive muscle loading, and proprioceptive challenges that collectively improve tolerance to movement and reduce perceived joint restriction. Previous work has emphasized that strengthening, balance, and functional exercise may improve osteoarthritis-related symptoms by addressing both local muscle performance and sensorimotor deficits around the knee (14).

The range-of-motion findings are particularly important because they indicate a clear mobility gradient between rehabilitation approaches. Knee extension gain was 5.17° in the MMG protocol group and 10.14° in the targeted knee exercise group, while knee flexion gain was 17.95° and 23.19°, respectively. These differences suggest that targeted exercise may be especially valuable when restoration of movement amplitude is a key rehabilitation goal. Improved knee flexion may translate into better performance of chair rise, stair negotiation, kneeling modification, and gait adaptability, while improved extension may contribute to more efficient stance phase mechanics and reduced compensatory loading. Although manual therapy can temporarily improve joint and soft-tissue mobility, repeated active movement under progressive load may produce more sustained adaptation by integrating range gain with muscle activation and functional control (15).

The WOMAC physical function findings require careful interpretation. At the aggregate level, WOMAC function improved by 21.40 points in the MMG protocol group and 19.81 points in the targeted knee exercise group. This indicates clinically meaningful functional improvement in both groups, despite larger targeted-exercise advantages in pain, stiffness, and range-of-motion outcomes. One possible explanation is that WOMAC function captures a broad range of daily activities influenced by multiple determinants beyond knee impairment alone, including baseline disability level, symptom duration, body mass index, habitual activity, confidence, and task exposure outside supervised therapy. Another possibility is that participants with greater baseline functional limitation may show larger absolute improvement simply because more recovery space is available. Because the present analysis is based on aggregate values, individual-level regression is required before concluding which baseline variables independently predict functional response.

These findings reinforce the need to distinguish between group-level effectiveness and patient-level prognosis. A treatment may produce statistically significant average improvement while individual patients vary substantially in the magnitude of recovery. In clinical rehabilitation, this distinction matters because two patients with the same radiographic grade may differ in baseline pain severity, functional limitation, body mass index, symptom chronicity, muscular performance, and capacity to adhere to exercise. The dataset used in this analysis contains several routinely collected baseline variables that could support future predictor modelling, including age, sex, body mass index, affected side, duration of symptoms, baseline pain, WOMAC domains, and baseline range of motion. However, such modelling requires participant-level data so that correlations, regression coefficients, adjusted odds ratios, and responder classifications can be calculated without ecological inference. The present aggregate analysis therefore provides a foundation for prognostic exploration but does not replace full individual-level prediction modelling.

From a clinical perspective, the recovery gradient observed in this analysis supports prioritizing progressive, targeted exercise when the therapeutic goal is improvement in pain, stiffness, and knee mobility. The stronger gains in flexion and extension suggest that active rehabilitation addressing strength, proprioception, and functional movement control may produce more comprehensive biomechanical improvement than a protocol dominated by manual soft-tissue techniques. At the same time, the substantial WOMAC function improvement in both groups indicates that manual-therapy-oriented care combined with conventional physiotherapy may still have meaningful value, particularly where pain modulation, treatment tolerance, or early movement facilitation is required. Therefore, the results should not be interpreted as excluding manual approaches, but as supporting the integration of active, progressive, and functionally specific exercise as a core component of Grade II knee osteoarthritis rehabilitation.

The study has important methodological strengths. The parent trial used a randomized allocation structure, a defined clinical population, repeated outcome measurement, and a blinded assessor, which improves confidence in the temporal pattern of recovery. Outcomes were clinically relevant and included pain, WOMAC domains, and goniometric range of motion, allowing the analysis to examine symptomatic, functional, and mobility dimensions rather than relying on a single endpoint. The 12-week follow-up period was sufficient to observe clinically meaningful rehabilitation change, particularly for active exercise adaptation. These strengths make the dataset appropriate for secondary clinical interpretation and future predictor analysis.

Several limitations should be acknowledged. First, the present results are derived from aggregate values reported in the thesis and manuscript; therefore, adjusted baseline-predictor modelling could not be completed without the raw participant-level dataset. Second, confidence intervals, standardized effect sizes, correlation coefficients, and regression estimates were not available in the supplied outputs, limiting the precision with which between-group recovery gradients can be interpreted. Third, some baseline descriptive variables showed denominator inconsistencies in the available manuscript text, particularly sex distribution, which should be resolved before final submission. Fourth, the sample included only patients with Grade II knee osteoarthritis aged 40–60 years, limiting direct generalizability to patients with more advanced radiographic disease, older adults, postoperative knees, inflammatory arthropathy, or secondary osteoarthritis. Finally, treatment adherence, home exercise compliance, analgesic use, physical activity level, and muscle strength were not available in the aggregate results, although these factors may strongly influence rehabilitation response.

Future work should complete the planned individual-level predictor analysis using the original dataset. The most clinically useful next step would be to calculate baseline-to-12-week change scores, classify functional and pain responders using a prespecified clinically meaningful threshold, and model whether baseline body mass index, symptom duration, baseline pain, baseline WOMAC function, baseline range of motion, and rehabilitation allocation independently predict recovery. Reporting adjusted regression coefficients or odds ratios with 95% confidence intervals would make the manuscript more consistent with its secondary-analysis objective and more useful for clinical decision-making. Additional sensitivity analyses stratified by symptom duration, baseline disability severity, and body mass index category would further clarify whether specific patient subgroups benefit more from targeted exercise or from combined manual-therapy and conventional physiotherapy approaches.

CONCLUSION

This secondary analysis showed that patients with Grade II knee osteoarthritis experienced meaningful 12-week improvement in pain, WOMAC domains, and knee range of motion following physiotherapy-based rehabilitation. The targeted knee exercise program demonstrated stronger recovery gradients for pain, stiffness, knee flexion, and knee extension, whereas WOMAC physical function improved substantially in both rehabilitation groups. These findings support the clinical value of progressive, functionally oriented exercise for symptom reduction and mobility restoration in early-stage knee osteoarthritis, while also indicating that functional recovery is influenced by multiple dimensions and should be interpreted beyond treatment allocation alone. Full participant-level predictor modelling is needed to determine which baseline demographic and clinical characteristics independently forecast meaningful rehabilitation response.

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