Effect of Modified Frailty Index on Postoperative Outcomes after Total Knee Arthroplasty

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ABSTRACT

Objective: To determine the impact of the modified frailty index (MFI) on patient-reported outcome measures (PROMs) using the knee injury and osteoarthritis outcome score (KOOS-12) following total knee arthroplasty (TKA).

Study Design: Prospective-observational study.

Place and Duration of the Study: Department of Surgery, Section of Orthopaedics, The Aga Khan University Hospital, Karachi, Pakistan, from August 2023 to July 2024.

Methodology: Sixty-six patients undergoing primary TKA were included, while those undergoing revision surgery were excluded. Each patient's frailty score was noted using the MFI. The primary outcome, KOOS-12 was collected preoperatively and at six weeks, three months, and six months postoperatively. Repeated measures ANOVA assessed the association of MFI and time on KOOS-12 scores.

Results: Patients with severe frailty levels showed significantly lower KOOS-12 scores at each time point, indicating low-grade improvement in outcomes in pain, function, and quality of life domains as compared to fit individuals. Severely frail patients had a mean KOOS-12 score of 26.3 ± 14.4 at admission, which improved to 65.5 ± 17.7 at six months, while non-frail patients showed higher baseline and follow-up scores. Repeated measures ANOVA results revealed significant effects of MFI level and time on KOOS-12 scores ($p < 0.001$), with significant improvement across all domains over time.

Conclusion: High frailty is associated with overall lower KOOS-12 score as compared to individuals with no frailty after TKA. These findings emphasise the value of frailty assessment in predicting functional outcomes and guiding preoperative counselling and postoperative rehabilitation to optimise recovery for frail patients undergoing TKA.

Key Words: *Knee, Osteoarthritis, Arthroplasty, Frailty, Outcomes*.

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INTRODUCTION

Knee discomfort with stiffness is among the most frequently reported complaints for visiting orthopaedic clinic with osteoarthritis (OA) as the most common.[1] In recent years, the prevalence of osteoarthritis has risen, affecting approximately 7.6% of people worldwide with a prevalence of 16.4% in South Asia.[2,3] Knee osteoarthritis has a detrimental effect on people's general quality of life and health, and can also place a significant financial strain on society.[4]

Several treatment options are available to manage knee OA, including lifestyle modifications for example avoiding activities that overbear the knee joint, strengthening exercises for muscles around the knee and weight loss.[5]

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It also includes methods that help to preserve cartilage such as intra-articular hyaluronic acid and regenerate cartilage such as intra-articular PRP.[5] Total knee arthroplasty (TKA) is an extremely effective method for relieving pain and enhancing daily living activities in people with advanced degenerative joint condition. Studies indicate that TKA leads to significant improvements in pain, function, and quality of life compared to continued non-operative management.[6] Henceforth, its demand continues to rise with evidence showing a 41.9% increase from the year 2006 to 2014.[7] Similarly, in Pakistan, due to the rise in non-communicable diseases, including joint diseases, the authors observed that 9.57 per 100,000 people underwent TKA i.e. 9,572 people had TKA between 2014 and 2021.[8]

TKA is a safe procedure and is associated with very little risk but potentially grave complications, providing an opportunity to predict and improve patient safety. Many models have been put forward for better risk stratification to predict complications after TKA.[9] Modified frailty index (MFI) is one such model that identifies people who are more prone to difficulties following surgical treatments. The index consists of 11 items that can be recorded from regular patient encounters. It has proven to be

effective in predicting adverse postoperative outcomes in many surgical specialities. [10]

The mean age of patients undergoing total knee replacement is 70 years in the US,[11] while in this part of the world, it is 61 years.[8] It is expected that these patients may have an increased prevalence of chronic diseases and deterioration of organ function as compared to healthy younger patients given the lower life expectancy.[12] Studies showed that as MFI increases, 30-day mortality and early postoperative complications also increase.[10] There are some data to show an association of MFI with functional improvement of daily activities after total hip replacement.[13]

Recently, patient-reported outcome measures (PROMs) have been used to monitor clinically meaningful improvements as a result of interventions.[14] The KOOS-12 is one of the reliable PROMs that has been used to assess patients' prognosis after TKA.[15]

The current study's objective was to assess the influence of MFI in PROMs after TKA at six weeks, three months, and at six months. This would enable to better counsel patients in the preoperative setting regarding postoperative outcome expectations depending on their preoperative status objectively based on their MFI score.

METHODOLOGY

This study was conducted prospectively at the Department of Surgery, Section of Orthopaedics, The Aga Khan University Hospital, Karachi, Pakistan, from August 2023 to July 2024. The study included patients who were electively admitted for TKA and gave informed consent. Patients undergoing revision knee arthroplasty or TKA secondary to neoplastic disease were excluded from the study. Patients' data were collected using a structured questionnaire after taking informed consent which included questions on patient demographics including age, gender, body mass index (BMI), ASA level, and comorbid conditions, along with questions to determine MFI and patient-reported outcome measures at four time points prospectively.

Preoperatively, the MFI of patients was evaluated. MFI consists of 11 variables that include functional status, history of diabetes, respiratory problems, congestive heart failure, myocardial infarction, cardiac problems, arterial hypertension, delirium, history related to cognitive impairment or loss, cerebrovascular problems, and history of stroke/decreased peripheral pulses.[16] MFI score was calculated by dividing the number of positive variables in the patient by the number of total variables which is 11. Grading of frailty is shown in Table I. The primary outcome measure was PROMs, which was measured using the KOOS-12 score on admission (preoperatively), and at six weeks, three months, and six months postoperatively. KOOS-12 tool evaluates knee-related symptoms across three domains – pain, function and quality of life. Each component had four questions which were graded from 0 to 4, that is from minimum to maximum. The response of each domain was scaled up to fall between 0 and 100, where a lower score meant worse and a score closer to 100 represented a better condition. This tool was selected because evidence shows that it is a valid and reliable measure for patients' knee problems, particularly moderate-to-severe knee osteoarthritis. Moreover, this short survey substantially reduced respondent burden and participants were able to complete it in under five minutes.[17] The KOOS-12 questionnaire and guidelines are publicly accessible at: https://www.koos.nu. Patients who missed in-person follow-up visits were contacted *via* telephone to complete the KOOS-12 assessment. The study was approved by the University's Ethical Review Committee (ERC No: 2023-8297-24090).

The sample size was calculated using $n = 8* CV2 [1+ (1-PC)^2] / (PC)^2$ where CV is the coefficient of variation and PC is the proportional change in KOOS scores. A minimum sample size of 61 adult patients was calculated with an inflation of 15% for loss to follow-up / non-response rate, to achieve 80% power with at least 10% change in mean KOOS scores and 30% or less change in coefficient of variation (ref) at two-sided 5% level of significance.

All patients underwent cemented posterior-stabilised TKA using the Zimmer System®. The median parapatellar approach was employed for all cases. Perioperative care included administration of 2 grams of intravenous cefazolin and 400 mg of ciprofloxacin as prophylactic antibiotics. Surgery was performed under a tourniquet, inflated to 150 mmHg above the patient's systolic blood pressure and deflated prior to wound closure to control bleeding. A single intravenous dose of 10 mg/kg tranexamic acid was administered after bone cuts were made.

Postoperative care included chemical thromboprophylaxis and 48-72 hours of antibiotic coverage. A standardised rehabilitation protocol was followed, beginning with quadriceps-strengthening exercises on the first postoperative day and progressing to stair climbing and full weight-bearing ambulation with a walker. Patients attended outpatient follow-up visits at two weeks for suture removal, followed by evaluations at six weeks, three months, and six months.

Statistical analysis was performed using STATA version 15.1. Qualitative data, such as gender, diagnosis, and ASA level were reported using frequencies and percentages. For quantitative data, normality distribution was checked using histograms and Shapiro-Wilk's test. Mean and standard deviations were reported for variables including BMI and age. For skewed data, median and interquartile ranges were reported. Moreover, both mean and median were reported for KOOS-12 scores at each time interval to ensure reporting consistency.[18] Data were cross-tabulated to compare different domains of KOOS-12 score over different time points with reference to levels of modified frailty index with KOOS-12 score. To further study the effect of MFI on knee health (KOOS-12) over time, the authors applied repeated measures ANOVA using means to maintain consistency in the analysis. This method examined the association of MFI and time, with respect to KOOS-12.

Table I: Knee injury and osteoarthritis outcome score (KOOS-12) of patients.

Domain	Admission	Time of assessment		
		Six weeks	Three months	Six months
Pain	33.1 (15.7)[a]	43.5 (16.4)[a]	67.9 (13.8)[a]	85.9 (13.5)[a]
	37.5 (18.7)[b]	43.7 (25)[b]	68.7 (18.7)[b]	90.6 (12.5)[b]
Function	33.4 (16.9)[a]	40.2 (16.8)[a]	64.1 (14.5)[a]	81.8 (15.3)[a]
	31.2 (18.7)[b]	43.7 (25)[b]	62.5 (18.7)[b]	87. 5 (18.7)[b]
Quality of life	26.8 (16.1)[a]	34.2 (16.2)[a]	55.1 (17.4)[a]	77.9 (18.9)[a]
	31.2 (25)[b]	31.2 (18.7)[b]	56.2 (25)[b]	84.5 (31)[b]
KOOS-12 overall	31.2 (13.7)[a]	39.3 (14.4)[a]	62.4 (13.6)[a]	81.9 (15.3)[a]
	31.2 (20.8)[b]	39 (21.1)[b]	63 (19)[b]	88 (23)[b]

The scores are reported as [a]Mean and standard deviation (SD), [b]Median and interquartile range (IQR). The values from the tool have been scaled to fall between 0 and 100 and the final KOOS-12 score is calculated as the average of the three domains.

Table II: Modified frailty index and knee injury osteoarthritis score of patients.

Modified frailty index (MFI)	Knee injury and osteoarthritis outcome score (KOOS-12)			
	Mean (SD)			
	Admission	Six weeks	Three months	Six months
Not frail (n = 12)	34.8 (13.6)[a]	44.2 (15.2)[a]	68.7 (15.6)[a]	90.5 (8.7)[a]
	35.4 (11.5)[b]	48 (19)[b]	70 (19.5)[b]	93 (7)[b]
Mild (n = 22)	31.5 (14.8)[a]	41.9 (41.9)[a]	66.4 (10.9)[a]	89.1 (7.8)[a]
	29.2 (18.7)[b]	41 (23)[b]	67 (19)[b]	92 (9)[b]
Moderate (n = 16)	32.6 (11.2)[a]	40.5 (9.9)[a]	63.5 (10.3)[a]	82.1 (11.6)[a]
	34.4 (22.9)[b]	42 (14)[b]	63 (14)[b]	84 (13)[b]
Severe (n = 16)	26.3 (14.4)[a]	31.1 (15.7)[a]	51.1 (12.5)[a]	65.5 (17.7)[a]
	22.9 (6.2–52.1)[b]	34 (23)[b]	47 (18.5)[b]	66 (23)[b]

[a]Mean and standard deviation (SD), [b]Median and interquartile range (IQR).

Table III: Repeated measures ANOVA analysis for knee injury and osteoarthritis outcome score (KOOS-12) with frailty of level of patients.

Outcome score	df	F	p-value
KOOS-12 overall[a]			
Between subjects			
Modified frailty index levels	3	6.51	<0.001
Error	62	-	-
Within subject			
Time	3	534.55	<0.001
Modified frailty index levels* time	9	3.37	<0.001
Error	9	-	-
Pain[b]			
Between subjects			
Modified frailty index levels	3	5.96	<0.001
Error	62	-	-
Within subject			
Time	3	457.5	<0.001
Error	195	-	-
Function[c]			
Between subjects			
Modified frailty index levels	3	2.56	0.06
Error	62	-	-
Within subject			
Time	3	300.2	<0.001
Error	195	-	-
Quality of life[d]			
Between subjects			
Modified frailty index levels	3	9.83	<0.001
Error	62	-	-
Within subject			
Time	3	285.9	<0.001
Error	195	-	-

The results were computed using repeated measures ANOVA, a p-value of <0.05 was considered statistically significant. Degrees of freedom (df). [a]KOOS-12 overall model with interaction: F = 30.83, df = 77, p <0.001 [b]Pain only model: F = 27.72, df = 68, p <0.001 [c]Function only model: F = 19.30, df = 68, p <0.001 [d]Quality of life only model: 19.10, df = 68, p <0.001.

RESULTS

A total of 70 patients underwent TKA during the study period, however, three did not meet the exclusion criteria and one patient suffered mortality due to myocardial infarction within 6 weeks. The final dataset consisted of 66 patients, among them 44 (66.7%) participants were ≥60 years old and the average age of patients was 63.6 ± 9.03 years. Compared to males, females were in greater proportion (55, 83.3%) and the most common diagnosis was osteoarthritis (56, 84.8%). The mean BMI was 31.4 (5.2), ASA level II and Kellgren Lawrence Grade IV were reported in 44 (66.7%) and 53 (80.3%) patients, respectively. Bilateral knee arthroplasty was performed in 38 (57.6%) patients, whereas unilateral knee arthroplasty was performed in 14 (21.2%) patients for each side. The median modified frailty index (MFI) was 0.09 (0–0.5), with 12 (18.2%) patients not frail, 22 (33.3%) mildly frail, 16 (24.2%) moderately frail, and 16 (24.2%) severely frail.

Table I shows the distribution of KOOS-12 score over time with respect to pain, function, and quality of life. The mean KOOS-12 score at the time of admission was 31.2 ± 13.7, it increased by 26% to an average of 39.3 ± 13.7 at six weeks. When assessed at three months, the score increased by 58.7% from the previous measurement to 62.4 ± 13.6. Lastly, at six months the mean score was 81.9 ± 15.3 which was a 31.2% increase from the previous measurement. The greatest difference was observed with respect to improvement in pain after TKA, which on average at the time of admission was 33.1 ± 15.7 and increased up to 85.9 ± 13.5, followed by functionality and lastly quality of life.

The further compared MFI levels with KOOS-12 score as shown in Table II. Patients who were classified as severely frail had the lowest mean KOOS-12 score on admission, 26.3 ± 14.4 and even six months after surgery their score was not considerably high (65.5 ± 17.7) compared to others. Patients who were mild and moderately frail had nearly similar mean

scores of 31.5 ± 14.8 and 32.6 ± 11.22 at the time of admission. Following improvement after TKA, their scores were in close proximity with patients with mild frailty achieving a greater KOOS-12 score of 89.1 ± 7.8 at six months.

Repeated measures ANOVA was conducted to examine the effects of MFI and time on KOOS-12 as shown in Table III. The observed significant effect of MFI levels on KOOS-12 score (F 6.51, df 3, p-value <0.001) showed that patients with different MFI levels had significantly different KOOS-12 levels. Moreover, the KOOS-12 score changed significantly with time (F 534.5, df 3, p-value <0.001). Additionally, the interaction between MFI levels and time demonstrated that the effect of time on KOOS-12 score differs across different categories of MFI (F 3.37, df 9, p-value <0.001). Further examination of this relationship with respect to each domain of KOOS-12 showed significant effects of function, and quality of life on KOOS-12 and marginally significant effect of pain. Time had a significant main effect on each outcome domain that is scores in pain, function and quality of life change over time.

DISCUSSION

The results showed that increasing frailty as evaluated by MFI is linked to lower KOOS scores compared to individuals with reduced frailty after TKA. However, even among frail patients, substantial improvements in KOOS scores are observed, leading to an overall enhancement in mobility and quality of life. This is similar to the study by Crook *et al*., which examined the impact of frailty on hip and knee arthroplasty.[19] The study found that fit individuals achieved the minimally important change in the Oxford Knee Score (OKS) compared to people with severe frailty. The study also showed that patient-reported success rates decreased with increasing frailty, with non-frail patients reporting much better or a little better after surgery compared with frail patients. Despite the impact of frailty on outcomes, the study indicated that even severely frail patients experienced significant improvements in their OKS scores, suggesting that knee arthroplasty does improve outcomes in this high-risk group of patients.[19]

Another study by Meessen *et al*. using the GFI as a frailty marker showed similar changes in KOOS scores preoperatively and one year postoperatively for frail and non-frail patients.[20] Frail patients demonstrated smaller improvements in the sports and quality of life subscales whereas improvement in pain was similar between the two groups. This suggests that while overall recovery is comparable, certain functional domains may be more affected by frailty.[20] Jiang *et al*. reported lower OKS in patients with comorbidities, though the specific number or types of comorbidities were not evaluated. Other factors such as worse preoperative OKS, diminished mental health, a BMI over 35 kg/m², living in deprived areas, higher ASA grades, and a history of knee surgery were also associated with worse outcomes.[21]

The study findings showed that despite frailty, changes in KOOS levels across all domains were significant. Pain improved in all patients, despite frailty level, as shown in Table III. This is in contrast to the study showing elderly frail patients were at risk for chronic post-surgical pain.[22]

This study showed that average age of patients undergoing knee arthroplasty was 63 years which is similar to the study by Beth *et al*., who found favourable outcomes in elderly people (average age 65 years) with TKA *vs*. non-operative management. This study also showed that 45% of patients were not offered operative treatment.[23]

Among the complications noted in the study, there was one mortality, post-operative myocardial infarction (MI) and acute urinary retention in the severely frail group. In the mild frail group, complications included acute kidney injury and one case of superficial wound infection. No other complications were reported.

Even though TKA in frail patients is associated with risk of complications, TKR provides a considerable increase in mobility, improves performance of daily activities, and can also reverse frailty levels. Surgeons should consider above-mentioned benefits of performing surgery in clinically indicated knee arthroplasty for frail patients.[24]

There is a lack of literature specifically examining the association of frailty with KOOS scores using the MFI. While GFI has been used as a frailty marker in some studies, the MFI is more commonly applied in surgical settings, especially in orthopaedic surgery and joint arthroplasty.[25] MFI offers a more detailed categorisation of frailty levels, allowing for a clear understanding of how different degrees of frailty affect PROMs. In contrast, the GFI only categorises patients as frail or not frail.

The study addresses the gap in the literature by concentrating on the relationship between KOOS scores and MFI at multiple postoperative time points (six weeks, three months, and six months), allowing for longitudinal evaluation of recovery trajectories. This approach provides valuable information about how frailty is associated with recovery at different points in time. This study will also help to enhance the understanding of how frailty affects functional recovery and inform clinical decision-making. Identifying frailty-associated risks can help guide rehabilitation strategies, ultimately improving outcomes for frail patients undergoing TKA.

The study has several caveats. The short follow-up period of six months could not fully capture the long-term recovery trajectory of frail patients after TKA. Longer follow-up is needed to better understand the sustained impact of frailty on functional outcomes. It is a single-centre study which limits the generalisability of findings to broader populations. There is a potential for selection bias as more frail patients requiring arthroplasty may not be represented in the sample due to preoperative screening. Moreover, the observed low

baseline score in the frail group could have resulted in slower recovery. Therefore, future studies with larger multicentre cohorts are needed to better understand the outcomes.

CONCLUSION

This study underscores the significant relationship between frailty as evaluated by MFI and PROMs in TKA patients. Non-frail patients report superior overall recovery, even though frail patients gradually see considerable improvements in their KOOS-12 scores. By including MFI assessment into standard preoperative screening, clinician decision-making, patient counselling, and postoperative rehabilitation may help construct patient-specific management strategies to optimise recovery and prognosis.

ETHICAL APPROVAL:
Approval was obtained from the Ethical Review Committee of the University Hospital (ERC No: 2023-8297-24090) was obtained before the initiation of the study.

COMPETING INTEREST:
The authors declared no conflict of interest.

AUTHORS' CONTRIBUTION:
MOF: Conception of the design, acquisition of data, writing of the manuscript, and responsible for integrity of research.
MT: Statistical analysis and reviewing of manuscript.
AS: Acquisition of the data and manuscript review.
SN: Conception of the design, reviewing, and final approval of the manuscript.
All authors approved the final version of the manuscript to be published.

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