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*Research article*

# Evaluating a Tailored 12-Week Post-Operative Rehabilitation Program for Younger Patients Following Total Knee Arthroplasty: Addressing a Growing Need

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**Abstract:** Background: The prevalence of total knee arthroplasties (TKA) is rising, especially among younger patients due to sports-related injuries and early osteoarthritis onset. Post-operative outcomes in younger patients show promise, but current rehabilitation approaches lack specificity for this group. This study aims to evaluate a post-operative rehabilitation program tailored for younger TKA recipients.; Methods: Patients from a single arthroplasty center who underwent TKA were age and sex-matched into two groups: Group A with an advanced 12-week rehabilitation program and Group B with a standard rehabilitation program. Eligibility required participants to be under 60 and ready for a specific TKA type, with assessments at baseline and 12 weeks post-operative using the KSS, KOOS, and the SF-36 scales. Results: At the 12-week follow-up, Group A, having received the advanced rehabilitation protocol, showed significantly higher KOOS (A: 85.1 ± 8.7 vs. B: 83.7 ± 11.1; p=0.042) and KSS (A: 82.9 ± 8.4 vs. B: 78.7 ± 9.2; p=0.020) scores than Group B. Both groups demonstrated marked improvements with an attendance rate of 88% (A) compared to 82% (B), although we found no significant difference in overall mean tolerability scores between the groups. Conclusions: Patients undergoing advanced rehabilitation after total knee arthroplasty showed significant improvements compared to standard protocols. Despite minor variations influenced by social determinants, the advanced protocol was more effective in post-operative recovery.

**Keywords:** Advanced rehabilitation; total knee arthroplasty; post-operative recovery

## 1. Introduction

In 2022, according to Romania's National Arthroplasty Register, a striking 6000 primary total knee arthroplasties (TKA) were performed, marking a substantial growth of 50% from 2020 and 20% compared to 2021 [1]. Projections indicate that this trend will persist, with an anticipated 25-30% increase in TKA procedures every five years [2, 3]. Though TKA has traditionally been more common in older populations, due to age-related degeneration, a rise in knee replacements among younger patients is on the horizon. This increase can be attributed to higher participation in sports, increasing the rate of ligament, meniscal, and cartilage injuries that subsequently accelerate the onset of osteoarthritis (OA) [4-6]. Symptomatic indicators for TKA are manifold and include pronounced pain, restricted range of motion, and substantial functional incapacitation. More nuanced indicators such as persistent articular stiffness, morphological deformities, and intractable pain resistant to conservative treatment [7, 8]. Upon successful completion of TKA and

adherence to rigorous rehabilitation protocols, patients often find themselves capable of resuming a range of activities, including walking, cycling, and low-impact aerobics [9]. Nonetheless, high-impact sports are generally not recommended due to potential risks to the prosthetic's longevity [10]. The primary aim of rehabilitation following TKA is focused on enhancing functional recovery, optimizing joint stability, and restoring range of motion. Although numerous randomized controlled trials have explored the efficacy of post-operative physiotherapy, the quality of these studies is often poor, and exercise adherence is rarely reported [11]. Current research suggest that younger and male patients tend to have better post-operative outcomes, showing greater improvements in mobility and activity levels in the first post-operative year [12]. In fact, some patients become more active in low-to-medium-impact sports post-surgery than they were prior to the onset of restrictive symptoms [13].

Despite the gradual accumulation of evidence supporting the benefits of TKA, gaps in our understanding persist, particularly concerning the return to sports, physical activity, and patient satisfaction among more youthful patients [14]. Currently, no rehabilitation programs are tailored specifically for this younger demographic. Our study aims to fill this gap by evaluating the feasibility, safety, and subjective patient reported outcomes of a 12-week post-operative rehabilitation program designed specifically for younger patients that underwent elective TKA. In this context, 'younger patients' are defined as individuals aged 30 to 60 years, a demographic that typically faces unique recovery challenges compared to the older population traditionally associated with TKA.

## 2. Materials and Methods

### *2.1. Study design*

A consecutive sample of patients who underwent the TKA procedure was obtained from the Clinic of Orthopedics and Traumatology in the County Hospital of Mures, a local center for knee and hip replacements. These patients were randomly age and sex-matched with controls who received standard rehabilitation protocols. A stratified block randomization was utilized, conducted through a computerized random number generator, to allocate participants into groups. This method ensured a balanced distribution based on age and baseline functional status, eliminating selection bias. Two groups were formed, respectively: Group A - advanced rehabilitation program (FastRehab), Group B - normal rehabilitation program. The clinic encompasses eight senior surgeons, that carry out approximately 300 total knee replacements each year, with most surgeons consistently performing more than 50 surgeries annually. Surgical approaches predominantly employed are the medial parapatellar and midvastus techniques. After undergoing surgery, all patients adhered to a regionally standardized clinical pathway, which involved a brief hospital stay of 5 to 7 days, followed by periodic standard follow-ups. Clinic visits were scheduled at 4, 8, and 12 weeks, with an additional yearly visit post-operatively. For their at-home rehabilitation, patients were provided with an extensive exercise program. This regime not only included range-of-motion activities and isometric knee strengthening exercises, but also involved activities such as stationary cycling, leg lifts, and step-ups without the use of additional supportive devices.

To be eligible for inclusion, participants had to be under 60 years of age, willing to undergo a unilateral TKA using a posterior stabilized endoprosthesis without patellar resurfacing, and demonstrate the ability to communicate efficiently. Conversely, individuals were excluded if they had posttraumatic or any other recognized type of secondary OA and also significant comorbid conditions such as: uncontrolled diabetes, cardiovascular diseases, or a history of previous knee surgeries apart from TKA.

Upon providing their written consent, participants in both groups underwent assessments at their pre-operative visit (baseline assessment). The baseline evaluation comprised gathering socio-demographic data, medical and surgical information and

history, and patients' pain and functional statuses via the Knee Society Score (KSS) and Knee Injury and Osteoarthritis Outcome Score (KOOS) and the SF-36 scale for assessing quality of life. Clinical charts were meticulously examined to extract relevant medical and surgical details. The final subsequent assessment took place at the 12-week post-operative consultation, marking it the culmination of the augmented rehabilitation program. This study received approval from the Ethical Board of Clinical County Hospital of Mureș (5014/15.04.2022).

*2.2. Advanced Rehabilitation Program*

In our outpatient study, young patients post-knee replacement participated in a structured 12-week rehabilitation regimen, comprising 2-hour individual exercise sessions, supervised by a certified physiotherapist. Participants engaged in these sessions four times weekly, totaling 24 sessions. Each session encompassed an hour of targeted land-based exercises. Initiating with a 5–10 minute warm-up on stationary bicycles, the regimen progressed to include comprehensive leg strengthening, core conditioning, balance exercises in both sitting and standing positions, flexibility drills, closed kinetic chain activities, and meticulous gait re-training. To optimize muscle engagement and strength recovery, resistance was gradually introduced using tools like therabands and lightweight free weights. A continuous passive motion device was used for 1 hour a day for all patients in Group A, starting 24 hours post-operatively. A detailed description of the program is illustrated in Table 1. The formulation of the rehabilitation program was meticulously aligned with the standards stipulated by the Consensus on Exercise Reporting [15].

**Table 1.** Comprehensive rehabilitation protocol (FastRehab) after TKA aligning with Consensus on Exercise Reporting Standards [15].

| Item Category | Abbreviated Item Description | Details |
|---|---|---|
| **Materials** | *Type of exercise equipment* | Resistance bands, stationary bicycle, balance board, leg weights, foam rollers |
| **Provider** | *Qualifications, teaching/supervising expertise* | Certified physical therapist with specialization in orthopedic rehabilitation and a minimum of 5 years of experience |
| **Delivery** | *Exercise performed individually or in a group* | Individually tailored sessions |
| | *Whether exercises are supervised or unsupervised* | First 4 weeks: Supervised, After: Combination of supervised and home exercises |
| | *Measurement and reporting of adherence to exercise* | Digital tracking via an app and weekly check-ins with the therapist |
| | *Details of motivation strategies* | Progress chart of PROMs, testimonials of past successes |
| | *Decision rules for progressing the exercise program* | Progress based on pain scale, range of motion improvements, and strength tests |
| | *Replication information* | Detailed exercise booklet with images and online video tutorials |
| | *Content of home program component* | Static and dynamic stretches, strength exercises combined with cycling on a stationary bike |

| | | |
|---|---|---|
| | *Nonexercise components* | Icing, elevation, compression, anti-inflammatory medication, as prescribed |
| | *How adverse events that occur during exercise were documented and managed* | Documented in the patient's digital profile and immediate modifications made to the protocol |
| **Location** | *Setting in which exercises were performed* | Orthopedic clinic center for supervised sessions; home for unsupervised sessions |
| **Dosage** | *Detailed description of the exercises (e.g., sets, repetitions, duration, intensity)* | Week 1-2: Low intensity, 2 sets of 10 reps (2h); Week 3-4: Moderate intensity, 3 sets of 12 reps (2h); Week 5 onwards: Gradual increase as tolerated (2h) |
| **What and how** | *Whether exercises are generic ("one size fits all") or tailored to the individual* | Tailored based on individual pain threshold, range of motion, and strength levels |
| | *Decision rule that determines the starting level for exercise* | Baseline assessment considering range of motion, strength, and pain levels |

*2.3. Standard Rehabilitation Program*

The standard rehabilitation program for Group B commenced with early mobilization, starting within 24 hours post-procedure. In the initial week, the primary focus was on pain alleviation, edema reduction, and basic joint mobilization exercises. By the end of the first week, we progressively transitioned to more intensive goals, aiming to achieve up to 105-degree knee flexion by the third week. This phase included systematic muscle fortification exercises targeting the quadriceps and hamstrings, coupled with functional training designed to enhance ambulatory capabilities. As participants progressed into the fourth week, the program emphasis shifted towards restoring advanced functional capacities. This included exercises for varied terrain walking and ingress and egress exercises, equipping patients for the transition to outpatient therapy or autonomous home-based regimens. Detailed booklets were provided to facilitate this transition, ensuring patients could continue effective self-managed exercises beyond the initial regimen.

*2.4. Outcomes*

In assessing the feasibility of the study, a multi-faceted approach was employed [16]. This encompassed an evaluation of the sustained involvement of participants over the 12-week rehabilitation programme, with a total of one year follow-up. Emphasis was placed on the use of distinct evaluation tools including KOOS scores, SF-36 scores, and KSS scores. The degree of commitment shown by participants to the intervention was quantified by the frequency of their attendance to rehabilitation sessions. Tolerability, conceptualized as the subjective experiences reported by patients after each therapeutic session, was systematically graded on a scale ranging from 0 to 10, a higher score meaning a good tolerability.

*2.5. Statistical analysis*

Descriptive statistics were initially utilized to overview participant demographics and baseline clinical data. An independent t-test was employed to determine differences in post-intervention outcomes, including KOOS, SF-36, and KSS scores, between the advanced and standard rehabilitation groups. Correlation coefficients were derived to elucidate the relationship between rehabilitation session attendance and score

improvements. Differences in tolerability between groups were assessed using a chi-square test. Multiple regression analyses were conducted to identify potential outcome predictors, considering variables such as age and surgical approach. All analyses upheld a 0.05 significance level, utilizing SPSS v.24 (SPSS Inc., Chicago, IL, USA).

## 3. Results

The study flow diagram detailing the research selection process can be comprehensively visualized in Figure 1. During the initial 4-week follow-up visit, two patients were lost to follow-up. Subsequently, at the second and final follow-up session, an additional three patients were unaccounted for, resulting in a cumulative loss of five participants over the course.

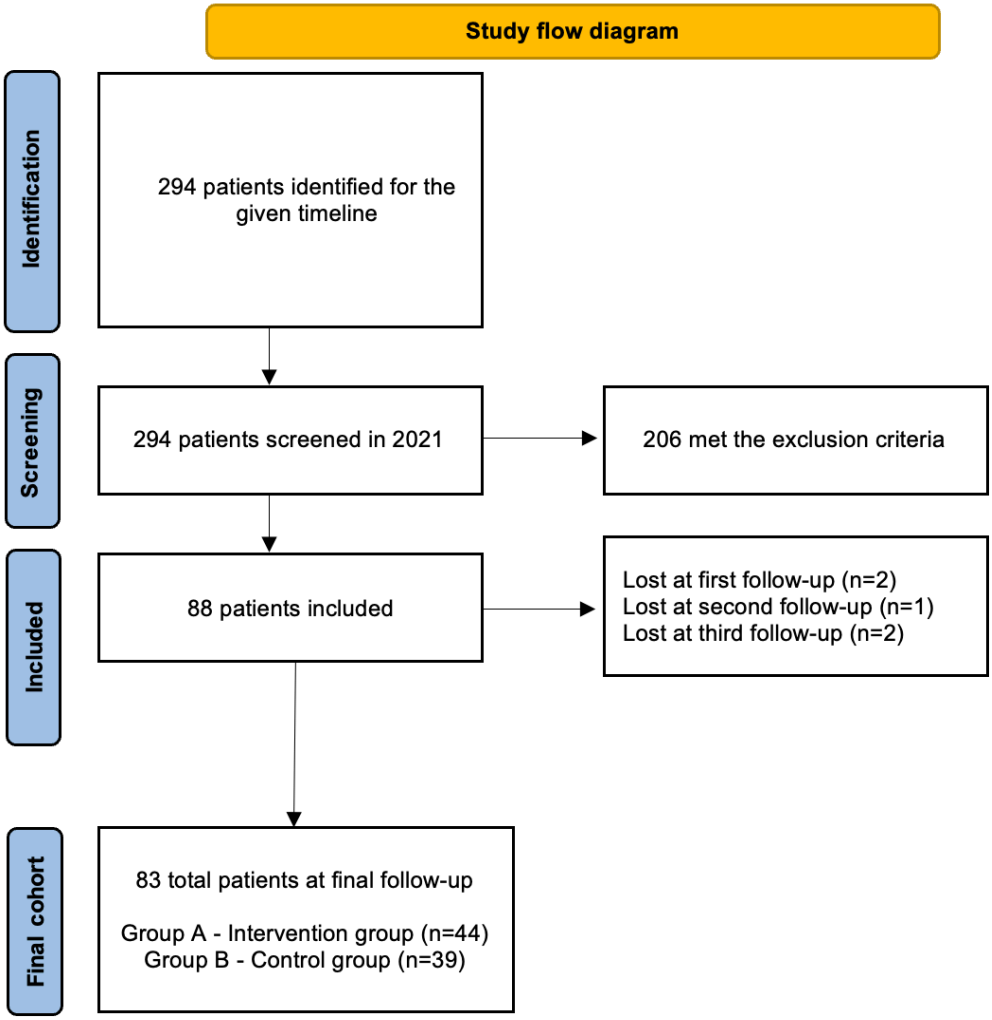


**Figure 1.** Participant Flow Diagram: Selection and Follow-up Attrition Over the Study Duration

To attain a comprehensive profile that ensures better understanding of participants background characteristics, a detailed overview of demographic and social determinants of health (SDoH) for both Group A (intervention group) and Group B (control group) are presented in Table 2. This encompasses a range of parameters, including age, gender, employment status, marital status, educational attainment, housing situation, insurance coverage, transportation means, smoking habits, and distance to the care facility.

**Table 2.** Demographics and SDoH for included patients.

| Demographic or SDOH item | Intervention group (n=44) | Control group (n=39) |
|---|---|---|
| **Age (mean ± SD)** | 49 ± 14.2 | 52 ± 22.1 |
| **Gender (n, %)** | | |
| - male | 15 (34) | 14 (36) |
| - female | 29 (66) | 25 (64) |
| **Employment status (n, %)** | | |
| - employed | 25 (57) | 22 (56) |
| - unemployed | 9 (20) | 7 (18) |
| - disability | 6 (14) | 5 (13) |
| - retired | 4 (9) | 5 (13) |
| **Marital status (n, %)** | | |
| - married | 26 (59) | 23 (59) |
| - single | 10 (23) | 9 (23) |
| - widowed | 4 (9) | 3 (8) |
| - divorced | 4 (9) | 4 (10) |
| **Education (n, %)** | | |
| - bachelors | 16 (36) | 14 (36) |
| - masters | 14 (32) | 12 (31) |
| - higher | 14 (32) | 13 (33) |
| **Housing status (n, %)** | | |
| - owned | 27 (61) | 24 (62) |
| - rented | 12 (27) | 10 (26) |
| - lives with parents or others | 5 (11) | 5 (13) |
| **Insurance status (n, %)** | | |
| - insured | 32 (73) | 28 (72) |
| - private insurance | 10 (23) | 9 (23) |
| - uninsured | 2 (4) | 2 (5) |
| **Transportation (n, %)** | | |
| - personal vehicle | 23 (52) | 20 (51) |
| - family vehicle | 12 (27) | 11 (28) |
| - public transportation | 9 (20) | 8 (21) |
| **Smoking status (n, %)** | | |
| - smoker | 8 (18) | 7 (18) |
| - past smoker | 6 (14) | 5 (13) |
| - non-smoker | 25 (57) | 22 (56) |
| - passive smoker | 5 (11) | 5 (13) |
| **Distance to care facility (n, %)** | | |
| - 1-50km | 32 (73) | 28 (72) |
| - 100km+ | 12 (27) | 11 (28) |

Employment status did not exert any significant impact on the outcomes for either the intervention or control group. Patients from the intervention group with a higher level of education notably scored better on the SF-36 mental health subscale (p=0.001) compared to those possessing only a bachelor's degree. The remaining social determinants of health

or demographic data were not found to exert a statistically significant impact on the final outcomes at any follow-up time.

At 12 weeks post-operative, Group A, which received the advanced rehabilitation protocol, demonstrated statistically significantly higher KOOS scores compared to Group B, which underwent the standard protocol, with a p-value of 0.042 (Table 3).

**Table 3.** Comparison of KOOS, SF-36, and KSS Scores between Intervention and Control Groups at 12 Weeks Follow-Up

| 12 weeks follow-up | Intervention group (mean ± SD) | Control group (mean ± SD) | *p*-value (t-test)* |
|---|---|---|---|
| KOOS score | 85.1 ± 8.7 | 83.7 ± 11.1 | 0.042 |
| SF-36 score | 72.1 ± 15.8 | 67.9 ± 19.9 | 0.012 |
| KSS score | 82.9 ± 8.4 | 78.7 ± 9.2 | 0.020 |

Moreover, a significant difference was observed in the KSS scores between the intervention group and control group (p=0.020). There was no difference between groups regarding quality of life assessed with SF-36 for either physical functioning or mental health subclasses.

The data illustrated in Figure 2 represents scores over time for the three different outcome scales scales for each scheduled follow-up time: KOOS, KSS, and SF-36. When comparing Group A and Group B over 12-weeks using the KOOS, KSS, and SF-36 scales, both groups exhibited significant progress.

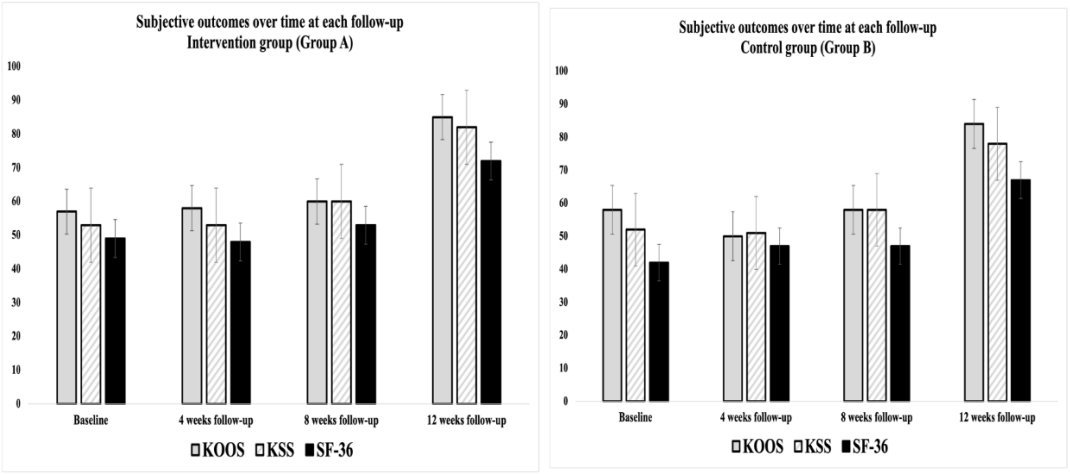


**Figure 2.** Comparative Progression between the intervention group and control group of KOOS, KSS, and SF-36 Scores for Group A and Group B Over a 12-Week Follow-Up Period

At baseline, their scores were quite similar, with Group A slightly below Group B in KOOS but slightly above in KSS and SF-36. By the 4-week follow-up, Group A maintained consistent scores, whereas Group B experienced a minor decrease in KOOS. At the 8-week mark, Group A's KOOS and KSS scores slightly surpassed those of Group B's. The most notable difference was observed at the 12-week follow-up, where both groups showed substantial improvements. Still, Group A edged out slightly with KOOS at 85.1 ± 8.7 versus Group B at 83.7 ± 11.1, KSS at 82.9 ± 8.4 against Group B at 78.7 ± 9.2, and in the SF-36 score with Group A at 72.1 ± 15.8 compared to Group B 67.9 ± 19.9. These differences suggest that patients who underwent an intensive rehabilitation protocol responded more favorably over time compared to our control sample of patients.

**Table 4.** Comparison of SF-36 Physical and Mental Component Scores Between The Intervention and Control Groups at Baseline and 12 Weeks

| SF-36 subscale | Intervention group (mean ± SD) | | Control group (mean ± SD) | | *p*-value (t-test)* |
|---|---|---|---|---|---|
| | baseline | 12 weeks | baseline | 12 weeks | |
| Physical component | 30.5 ± 9.2 | 42.7 ± 7.1 | 28.3 ± 10.1 | 40.9 ± 8.3 | <0.001 |
| Mental component | 18.6 ± 8.3 | 29.4 ± 6.5 | 14.6 ± 8.9 | 27.0 ± 7.6 | <0.001 |

*calculated comparing the intervention group and control group at final follow-up

Marked improvements were observed over the 12 week period for both physical and mental components of SF-36 questionnaire (Table 4). At baseline, the physical component scores were comparable between the intervention group (30.5 ± 9.2) and the control group (28.3 ± 10.1). By the 12-week mark, substantial score improvements were evident in each group; however, the intervention group showcased a slightly higher mean score of 42.7 ± 7.1 compared to the control group's 40.9 ± 8.3 ($p<0.001$). Similarly, in the mental component, both groups manifested an uptrend, with the intervention group elevating from 18.6 ± 8.3 to 29.4 ± 6.5, while the control group improved from 14.6 ± 8.9 to 27.0 ± 7.6 ($p<0.001$).

**Table 5.** Tolerability and Attendance Rate Comparison between the Intervention and Control Groups at Final Follow-Up

| Group | Overall mean attendance rate | Overall mean tolerability score | *p*-value (chi)* |
|---|---|---|---|
| Intervention group (A) | 88% (8.8/10) | 8.3 | 0.076 |
| Control group (B) | 82% (8.2/10) | 8.9 | |

*tolerability score comparison calculated between the intervention and control group at final follow-up

An overall mean attendance rate of 88% (8.8 out of 10 sessions) was observed for the intervention group, whereas the control group exhibited a rate of 82% (8.2 out of 10 sessions). A marginally elevated overall mean tolerability score of 8.9 was reported for the control group in comparison to the 8.3 of the intervention group (Table 5). Upon comparison of tolerability scores between the two groups at the final follow-up, no statistically significant difference was identified ($p= 0.076$).

## 4. Discussion

The current study elucidates the comparative effectiveness of an advanced exercise rehabilitation program (FastRehab) versus a conventional regimen in younger TKA patients. In the group of patients subjected to the advanced rehabilitation protocol, there was a discernible enhancement in the PROMs relative to those exposed to the standard rehabilitation protocol. During the cumulative follow-up duration of three months, no significant alterations in their quality of life were observed. The increasing integration of PROMs in arthroplasty registries should emphasize that outcomes paramount to patients like pain alleviation and functional restoration, offer insights into value-based care, assist surgical decision-making, and potentially improve surgical timing [17]. At the final follow-up of three months post-operative, the cohort subjected to FastRehab manifested statistically significant enhancements in KOOS scores compared to their counterparts who underwent the standard rehabilitation regimen. The KSS and SF-36 evaluations for the advanced rehabilitation cohort reflected a progressive, favorable trajectory when

compared to the standard group, on all item score subscales. These observations underscore the potential of a meticulously curated, intensive rehabilitation protocol in amplifying functional subjective outcomes and elevating the quality of life for young TKA recipients [18]. The boundary in outcomes between the two groups stresses the importance of a comprehensive rehabilitation strategy post-TKA, especially for younger patients. Given the increasing number of younger individuals who have indications for TKA, it is paramount that post-operative care is structured to expedite recovery and ensure long-term joint functionality [19]. Recent interdisciplinary research has highlighted that fast rehabilitation following total knee arthroplasty significantly reduces inpatient length of stay [20]. While immediate functional recovery trajectories between rapid rehabilitation and control groups did not differ significantly, patients in the rapid rehabilitation cohort were 2.5 times more likely to exhibit a positive trajectory in their physical therapy rehabilitation.

Interestingly, the study demographic analysis revealed a positive correlation between higher educational levels and improved SF-36 mental health subscale outcomes in our intervention group. This underscores the potential influence of socio-economic factors and their interconnectedness with post-surgical rehabilitation outcomes [21]. The fact that the intervention group which underwent a more rigorous protocol, showed a higher attendance rate compared to control, suggests a probable patient perception of tangible benefits derived from the advanced program. This slightly contrasts with the marginally higher tolerability scores in the control group. It implies that while the advanced program might be perceived as more challenging, its benefits might justify the rigorous nature, leading to better adherence. As evidenced by a systematic review and following our findings, while specific modalities such as continuous passive motion and inpatient rehabilitation may not offer additional advantages, strategies encompassing early rehabilitation, outpatient therapy, and high-intensity exercises have showcased potential efficacy and increased patient adherence to them [22].

We acknowledge the potential for certain biases that could influence the results. One such bias is performance bias, which may arise from differences in the care provided apart from the intervention being studied. To mitigate this, both groups A and B received their respective rehabilitation programs under closely monitored conditions with standardized protocols that ensure consistency in treatment delivery. Another concern was detection bias, which in this study refers to differences in outcome assessment. To minimize this, outcomes were evaluated by professionals blinded to the group allocation, ensuring that their assessments were not influenced by knowledge of the treatment received. Additionally, patient-reported outcomes were collected using standardized, validated tools to further reduce the risk of subjective bias.

The loss of five participants over the study duration, albeit seeming marginal, might have had an impact on the outcomes and can be considered a limitation. Furthermore, the study was conducted in a single center, with patients being operated by different senior surgeons, potentially limiting the generalizability of findings to more comprehensive and diverse populations. The sample size in our study could also potentially serve as a limitation, potentially affecting the robustness of the conclusions presented. Addressing these limitations in future research by expanding the sample size, ensuring consistent surgical teams, and involving multiple centers will be crucial in providing more validity of the results.

The advanced rehabilitation program demonstrates tangible benefits for younger TKA patients by enhancing functional outcomes and overall quality of life. Building on these findings, future research could delve deeper into tailoring rehabilitation regimens according to individual patient needs, more personalized, with a special focus on socioeconomic determinants. Additionally, further studies could investigate the program

effectiveness across different subgroups within the younger patient demographic, such as varying levels of pre-operative fitness or occupational demands. Another promising area for research is comparing our tailored program with other rehabilitation approaches, including those integrating innovative technologies or alternative physiotherapy methods. These explorations could significantly contribute to personalized and socioeconomically sensitive care strategies in orthopedic rehabilitation, particularly for younger TKA patients.

## 5. Conclusions

The advanced exercise rehabilitation program has demonstrated superior outcomes in knee functionality and quality of life metrics when compared to standard post-operative rehabilitation in younger TKA patients. The findings underscore the significance of adopting comprehensive and tailored rehabilitation strategies for this demographic, who may have unique post-operative needs and expectations.

The positive correlation between higher educational levels and improved mental health outcomes within the intervention group suggests the intertwined nature of socioeconomic factors and post-operative outcomes. This understanding can guide future patient-centric care approaches.

**Author Contributions:** All authors contributed equally for the development of this article. Conceptualization, L.V. and O.R.; methodology, A.M.F.; software, S.G.Z.; validation, L.V., O.R. and G.T.S.; formal analysis, T.S.P.; investigation, A.M.F.; resources, S.G.Z.; data curation, O.R.; writing—original draft preparation, T.S.P.; writing—review and editing, L.V. and T.S.P; visualization, A.-M.F.; supervision, S.G.Z.; project administration, T.S.P.All authors have read and agreed to the published version of the manuscript.

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**Institutional Review Board Statement:** The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Clinical County Hospital of Mureș (protocol code 5014 and 15/04/2022)

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

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**Data Availability Statement:** Not applicable.

**Conflicts of Interest:** The authors declare no conflict of interest

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