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Acceptability and early outcomes of an automated telemonitored smartphone rehabilitation programme after total knee arthroplasty

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Dear Editor,

The global burden of chronic disease continues to rise, driven by population ageing and improved survival following acute medical conditions, which increase demand for rehabilitation services.[1] Total knee arthroplasty (TKA) is one of the most commonly performed elective orthopaedic procedures, with more than 3300 cases annually in Singapore and continued growth expected in the coming decades.[2] Although postoperative rehabilitation optimises recovery of mobility, strength, and function, access to conventional face-to-face physiotherapy may be constrained by workforce limitations,[3] healthcare costs, and logistical barriers. These challenges highlight the need for scalable rehabilitation models that maintain clinical effectiveness while improving accessibility and reducing reliance on therapist-delivered care.

Tele-rehabilitation has emerged as a promising approach to improve access to rehabilitation while maintaining clinical outcomes.[4,5] Previous studies have demonstrated that tele-rehabilitation can achieve outcomes comparable to those of conventional rehabilitation after TKA. However, many existing models rely on synchronous therapist-led sessions or additional wearable devices, limiting scalability within healthcare systems.[6] A previous home-based telemonitored rehabilitation programme demonstrated promising outcomes after TKA.[7] However, its reliance on a physical monitoring device may present barriers to broader implementation.

To address these limitations, the authors developed a fully automated smartphone-based telemonitored rehabilitation (TR) programme using built-in smartphone functions and clinically validated patient-led assessments to monitor recovery trajectories and provide automated feedback and criterion-based progression without synchronous therapist supervision.[8,9] Normative recovery data were incorporated to support personalised rehabilitation progression.[10] The authors conducted a pilot randomised controlled non-inferiority trial to evaluate the safety, acceptability, and preliminary effectiveness of TR compared with conventional hospital-based rehabilitation (HBR) after TKA.

Thirty patients undergoing primary unilateral TKA were randomised 1:1 to TR (n=16) or HBR (n=14) using REDCap, with allocation stratified by baseline fast gait speed and random block sizes of 4 and 6. Eligibility criteria included age ≥45 years, independent preoperative ambulation, and ability to use a smartphone application in English or Mandarin. Patients with major neurological conditions or planned discharge to step-down facilities were excluded. As this was a pilot feasibility study, the sample size was determined pragmatically.

HBR participants received standard preoperative physiotherapy education followed by postoperative physiotherapy, with at least 4 sessions over 12 weeks in addition to prescribed home exercises. Treatment and progression were tailored according to individual assessment findings. TR participants received the same preoperative physiotherapy education, with additional physiotherapist-led onboarding to the smartphone application, followed by automated criterion-based rehabilitation using the same clinical guidelines as HBR. Both groups received a standard postoperative home physiotherapy visit at approximately 1 week. For TR, this additionally reinforced app use. Thereafter, TR participants continued the remaining 11 weeks of rehabilitation using the smartphone programme, involving knee range-of-motion and 5-repetition sit-to-stand self-assessments, automated progression, and asynchronous monitoring. Deviations from expected recovery or patient requests prompted arrangement of an in-person physiotherapy session.

The primary outcome was 12-week fast gait speed. Secondary outcomes included Knee Injury and Osteoarthritis Outcome Score (KOOS), pain, strength, knee range-of-motion, and sit-to-stand performance. As automated rehabilitation shifts greater responsibility to patients, acceptability and engagement are

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Table 1. Acceptability and effectiveness outcomes.

Acceptability[a]	**HBR (n=14)**	**TR (n=16)**	**aOR (95% CrI)**[b]	***P* (OR>0.90)**	***P* (OR>0.95)**[c]
EARS[d]	79.8 (21.9)	79.5 (14.9)	0.9 (0.4–2.2)	49.9	45.4
Satisfaction	8.6 (1.6)	7.5 (3.2)	0.8 (0.3–2.0)	43.6	39.2
GRS function[e]	85% (12)	85% (14)	0.8 (0.3–2.5)	39.8	37.0
Effectiveness[f]	**HBR (n=14)**	**TR (n=16)**	**Difference (95% CrI)**[g]	**P(N-I)**	**P(N-I)**[h]
Primary: Fast gait speed (0.10 metre/second)					
Baseline	1.33 (0.33)	1.36 (0.31)			
Week 12	1.37 (0.40)	1.50 (0.30)	0.06 (–0.09 to 0.21)	98.1	93.4
30s-STS (1.9 reps)					
Baseline	9.9 (4.4)	10.2 (3.6)			
Week 12	10.1 (4.3)	12.4 (4.4)	1.4 (–1.1 to 3.8)	99	95.9
1 RM (5 lbs)					
Baseline	26.4 (21.1)	35.0 (29.2)			
Week 12	25.8 (14.7)	29.2 (16.2)	1.1 (–6.5 to 8.3)	93.8	82
Flexion (9 deg)					
Baseline	114 (14)	115 (15)			
Week 12	113 (9)	109 (9)	–4 (–9 to 2)	97.9	65.2
Extension (6.3 deg)					
Baseline	4.1 (4.2)	5.6 (6.3)			
Week 12	1.5 (4.9)	3.3 (7.0)	–0.1 (–3.9 to 3.4)	99.9	94.4
KOOS (10 points)					
Baseline	63 (16.4)	67 (16.3)			
Week 12	81 (15.5)	87 (9.67)	4 (–4.7 to 12.9)	>99.9	98
Pain intensity (1.7 points)					
Baseline	5.2 (2.2)	4.9 (2.6)			
Week 12	2.6 (2.1)	1.6 (1.5)	0.9 (–0.6 to 2.2)	>99.9	99.1

CrI: credible interval; EARS: Exercise Adherence Rating Scale; GRS: Global Rating Scale; HBR: hospital-based rehabilitation; KOOS: Knee Injury and Osteoarthritis Outcome Score (physical function subscale); P(N-I): probability of non-inferiority; OR: odds ratio; RM: repetition maximum; SD: standard deviation; STS: sit-to-stand; TR: telemonitored rehabilitation

[a] Data are mean (SD); no. or mean (proportion); no.

[b] Between-group differences at the month-3 postoperative timepoint were presented as ORs (95% CrI) and derived from Bayesian ordinal regression models. All models were adjusted for age and sex. Adjusted ORs were computed by comparing TR with HBR, such that ORs>1.0 indicate that patients reported better outcomes with home-based telemonitoring rehabilitation than with hospital-based rehabilitation.

[c] The probability of non-inferiority was based on the posterior probability distribution of ORs not exceeding (1) the non-inferiority margin of 0.90 and (2) the more conservative threshold set at 0.95.

[d] EARS score was inverted, with higher values (up to 100) indicating maximal exercise adherence.

[e] Patients were classified as having improved if they reported a meaningful improvement in overall function.

[f] Data are mean (SD) using modified intention-to-treat data.

[g] Between-group differences (95% CrI) at 12-week follow-up were derived from Bayesian mixed-effects robust linear regression models. All models were adjusted for age, sex, and baseline (preoperative) outcome measure. Data are presented such that positive values indicate that patients had better pain and functional outcomes with home-based telemonitoring rehabilitation than with hospital-based rehabilitation.

[h] For a given outcome measure, the probability of non-inferiority was based on the posterior probability distribution of treatment differences not exceeding (1) the prespecified non-inferiority margin given by the value in parentheses and (2) the more conservative threshold set at 0.75 of the non-inferiority margin.

important determinants of successful implementation. Acceptability outcomes included usability assessed using the user version of the Mobile Application Rating Scale (uMARS), exercise adherence, patient-reported satisfaction, and global perceived recovery, reflecting both technology-related experience and patient acceptance of the rehabilitation model. Although the intervention was open-label, outcome assessors were masked to group allocation. Outcomes were analysed using Bayesian regression models with non-inferiority margins pre-specified a priori based on published clinically meaningful differences or minimum detectable change values, where available.

Of the 30 participants randomised, 26 (87%) completed the 12-week outcome assessment (HBR, n=14; TR, n=12). HBR participants completed a median of 4 rehabilitation sessions, and no crossover from TR to HBR occurred. Baseline characteristics were comparable between groups (mean age 64.4 years; 70% female). No serious intervention-related adverse events occurred. Two non-rehabilitation-related wound infections requiring readmission occurred in TR within 2 weeks postoperatively. Subsequent rehabilitation was provided as clinically required.

Exercise adherence and app usability were favourable. Exercise adherence was high and comparable between groups, with mean Exercise Adherence Rating Scale (EARS) scores of 79.8 (standard deviation [SD] 21.9) in HBR and 79.5 (SD 14.9) in TR. The TR application was rated positively on uMARS, with high functionality (4.3/5), aesthetics/information quality (4.2/5), and behaviour-change impact (4.4/5), although engagement was moderate (3.7/5). However, patient satisfaction and global perceived recovery showed lower probabilities of non-inferiority (approximately 37–46%), favouring HBR (Table 1).

At 12 weeks, TR demonstrated a 98% posterior probability of non-inferiority to HBR for fast gait speed (adjusted mean difference metre/second; 95% credible interval −0.09 to 0.21). Secondary outcomes, including KOOS, pain intensity, quadriceps strength, and knee range-of-motion, also showed >93% probability of non-inferiority. Findings were consistent in sensitivity and per-protocol analyses (Table 1). Despite comparable clinical outcomes, lower satisfaction and perceived recovery scores in TR highlight the importance of patient experience and may reflect patients' preferences for therapist interaction, reassurance, and therapeutic relationship during early recovery. Thus, favourable usability and adherence do not necessarily translate into equivalent patient experience compared with therapist-led rehabilitation. Hybrid models combining automated rehabilitation with targeted therapist input may therefore balance scalability with personalised support.

This study is limited by its small sample size and inclusion of relatively high-functioning, technologically capable participants, reflecting the initial target population for automated rehabilitation and limiting generalisability to broader TKA populations. The open-label design may also have influenced patient-reported outcomes.

In conclusion, this pilot trial provides preliminary evidence that a fully automated smartphone-based telemonitored rehabilitation programme following TKA is safe, demonstrates favourable usability and exercise adherence, and achieves non-inferior functional outcomes compared with conventional hospital-based rehabilitation. However, patient satisfaction and global perceived recovery favoured HBR, highlighting the importance of patient experience when considering automated rehabilitation. This study extends existing evidence by demonstrating that an automated model without synchronous therapist input can deliver comparable functional outcomes while maintaining adherence and usability among selected patients. Larger trials are warranted to evaluate long-term effectiveness, cost-effectiveness, and implementation across broader populations.

Ethics statement

The study was approved by the SingHealth Centralised Institutional Review Board (2023/2482), and all participants provided written informed consent. The trial was prospectively registered at ClinicalTrials.gov (NCT06248034).

Declaration

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