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Review

The effect of mobile application-based rehabilitation in patients with total knee arthroplasty: A systematic review and meta-analysis

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HIGHLIGHTS

- A meta-analysis of the effect of mobile app-based rehabilitation in total knee arthroplasty (TKA) have not been presented.
- The mobile-application based telerehabilitation provides more effective results in pain and range of motion in TKA.
- Furthermore, meta-analysis results demonstrated the importance of mobile device-based telehealth on function in TKA.

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ABSTRACT

Objective: Mobile applications have been used frequently in post-operative orthopedic rehabilitation in recent years. However, no systematic review has emphasized the importance of mobile applications in the rehabilitation process after total knee arthroplasty (TKA). This systematic review and meta-analysis aimed to evaluate the effectiveness of mobile application-based rehabilitation practices in patients with TKA.
Material and Methods: PubMed, Web-of-Science, Scopus, ScienceDirect and Cochrane databases were searched. The Physiotherapy Evidence Database (PEDro) and the Revised Cochrane risk-of-bias tool randomized trials 2 (RoB2) tools were used to demonstrate the methodological quality and risk of bias.
Results: A total of 584 articles were screened. Finally, six papers were included in the systematic review. PEDro scores ranged from 4 to 7 (median: 5.5), indicating fair to good methodological quality. All studies were classified as "some concerns" in RoB2. Mobile application-based rehabilitation demonstrated better scores on pain, range of motion (ROM), objective and subjective function, satisfaction and compliance in general. Meta-analysis proved that mobile application-based telerehabilitation demonstrated better results on subjective function (ES:0.57, 95% CI: 0.11–1.02).
Conclusion: Compared to conventional rehabilitation, application-based telerehabilitation provides more effective results in function, pain and ROM. Furthermore, mobile application-based rehabilitation should also be considered regarding patient satisfaction and compliance.

1. Introduction

Post-operative rehabilitation is essential to increase the effectiveness of total knee arthroplasty (TKA) (Lenssen et al., 2008). In recent years, accelerated and enhanced rehabilitation protocols have aimed to restore patients' function and quality of life more effectively (McDonald et al., 2012; Ranawat & Ranawat, 2007). In addition to physical performance, psychological outcomes (e.g., satisfaction, expectation, engagement) should be considered during the rehabilitation (Canovas & Dagneaux, 2018; Özden et al., 2021; Ponzio et al., 2018).

Effective patient-clinician communication should also be ensured during the rehabilitation process to achieve better results in clinical outcomes (Fennema et al., 2014; Zeng et al., 2020). Considering that patients are discharged in approximately one to two years, the significance of monitoring individuals at home becomes even more evident (Bovonratwet et al., 2019; Nowak & Schemitsch, 2019). Moreover, remote follow-up is even more critical, considering that patients reach their functional capacity in the sixth month after the surgery (Jones et al., 2003).

In this context, telerehabilitation has provided positive results in

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postoperative treatment (Jiang et al., 2018; Shukla et al., 2017).

Telerehabilitation provides remote education, care, physiotherapy, and consultation services (Buckingham et al., 2022). After TKA, patients should be educated in terms of daily living activities and exercises to ensure the continued success of the surgical procedure and to maintain the integrity of the muscular structures surrounding the prosthesis (Hohler, 2008). Quasi-experimental and randomized controlled trials recently focused on the effectiveness of remote training, care and rehabilitation programs after TKA (Moffet et al., 2015; Russell et al., 2011; Tousignant et al., 2011). Mobile app-based telerehabilitation has been demonstrated to increase accessibility (Huang et al., 2017; Ramkumar et al., 2019; Tripuraneni et al., 2021), improve satisfaction/compliance (Bäcker et al., 2021; Hardt et al., 2018; Huang et al., 2017), and reduce the need for emergency consultation and

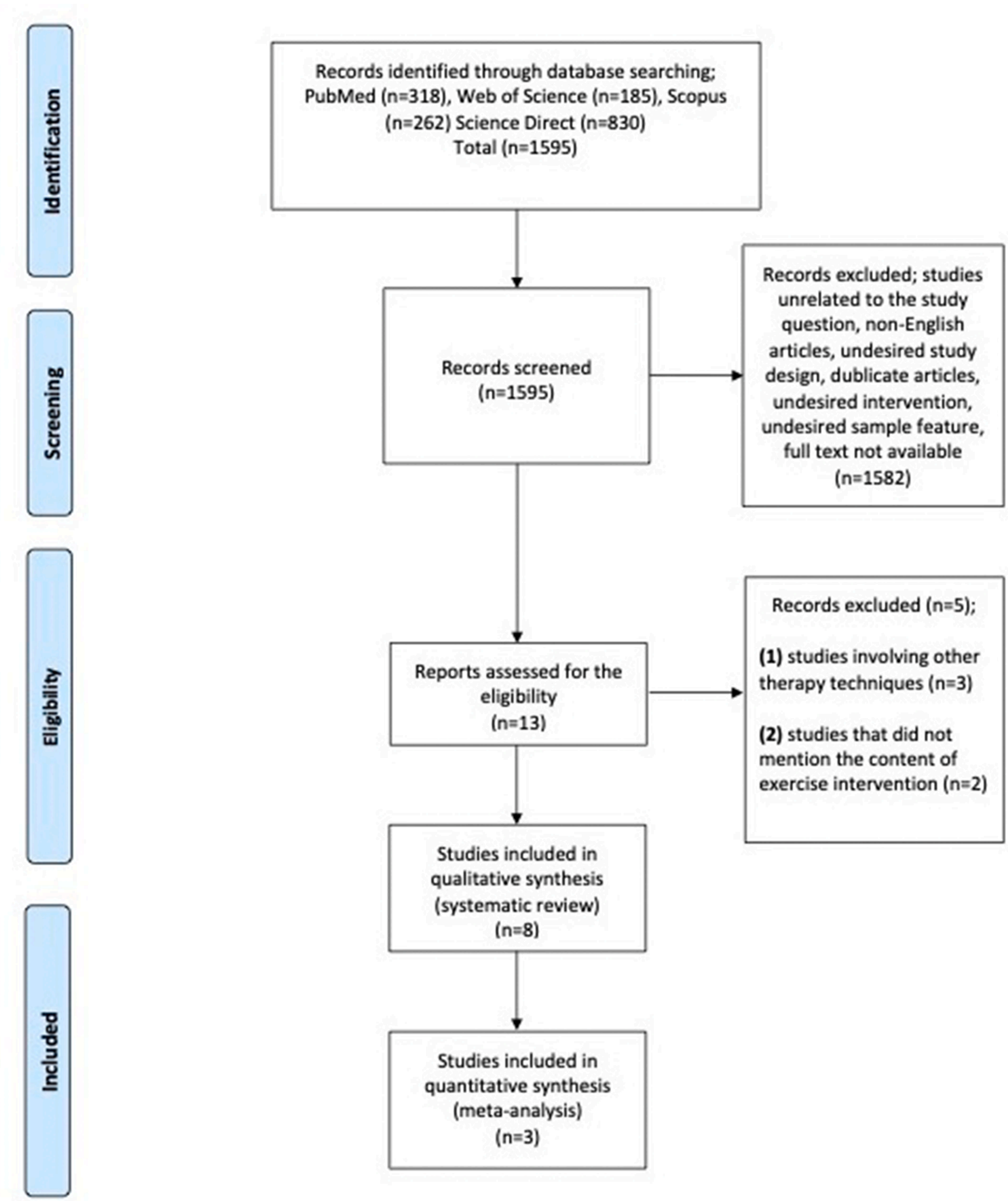

Fig. 1. PRISMA flow diagram of the study.

physiotherapy (Crawford et al., 2021) in individuals with TKA.

Recent studies have extensively reported the effectiveness of mobile app-based telerehabilitation applications in knee arthroplasty rehabilitation (Huang et al., 2017; Ramkumar et al., 2019; Tripuraneni et al., 2021). However, no systematic review has emphasized the importance of mobile applications in the rehabilitation process after TKA. This systematic review and meta-analysis aimed to evaluate the effectiveness of mobile application-based rehabilitation practices in patients with TKA.

2. Methods

2.1. Search strategy and selection criteria

"Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA)" were used during this review (Moher et al., 2009). PubMed, Web-of-Science, Scopus, ScienceDirect and Cochrane databases were searched from December 2021 to January 2022. "Medical Subject Headings" was used to identify keywords. Details on the search strategy are presented in Appendix 1.

2.2. Eligibility criteria

The inclusion criteria are; (1) randomized controlled trials (RCTs), (2) studies including post-operative knee arthroplasty cases, (3) studies involving treatment intervention including mobile application-based education, care, rehabilitation or combinations.

The exclusion criteria are; (1) quasi-experimental and pilot studies, (2) articles containing conservative and other invasive interventions within the scope of rehabilitation (e.g., drug, steroid injection, acupuncture), (3) only abstracts, (4) studies including both knee and hip arthroplasty cases.

2.3. Study selection and data extraction

In the literature review, output files of 584 articles were obtained from relevant databases. These files were imported into Rayyan software (QCRI, Qatar) (Ouzzani et al., 2016). Duplicate publications were excluded by Rayyan software. After the screening, two researchers determined that 15 studies were eligible for review. In a more detailed analysis of the full texts, nine studies were excluded for various reasons (Fig. 1). In cases where two researchers could not reach consensus, the decision of the third consultant researcher was considered. Finally, six studies were included in the systematic review. Three studies were suitable for data pooling in meta-analysis. Table 1 presents the characteristics of the six studies (e.g., age, outcome measures, intervention, and details of outcomes).

2.4. Quality and risk of bias assessment

Two clinical researchers assessed the risk of bias and methodological quality. “Revised Cochrane risk-of-bias tool randomized trials (RoB2)” was used for risk of bias evaluation. RoB2 provides a bias risk assessment within the scope of signaling questions in 5 domains. The algorithm of the software categorizes the studies in “low risk”, “some concerns” or “high risk” (Sterne et al., 2019).

PEDro scale was used for methodological quality assessment. PEDro includes 11 dimensions ("Eligibility criteria, random allocation, concealed allocation, baseline comparability, blind subjects, blind therapists, blind assessors, adequate follow-up, intention-to-treat analysis, between-group comparisons, point estimates and variability"). A total score of 9–10 is categorized as "excellent", 6–8 as "good", 4–5 as "fair", and 0–3 as "poor" quality (Sherrington et al., 2000).

2.5. Evidence synthesis and meta-analysis

Studies showing heterogeneous structures were presented within the scope of qualitative analysis. The narrative synthesis was presented according to the stages of “primary synthesis, identifying the relationship in and between studies, and deciding the accuracy of the synthesis” (Popay et al., 2006). In the quantitative analysis, three studies showing homogeneity were pooled for "active ROM" and "Knee injury and Osteoarthritis Outcome Score (KOOS) Jr".

Meta-Mar software (Philipps-Universität Marburg, Germany) was used for the statistical analysis. The standardized mean difference (SMD) was calculated considering the “change of mean”, “standard deviation (SD)”, and” sample size” of the studies (Andrade, 2020). Reference values for the SD of the "change scores" were determined using the guidelines of the Cochrane Handbook (Higgins et al., 2019).

3. Results

3.1. Screening results

A total of 584 articles [(Web of Science ($n = 44$), Cochrane Library ($n = 50$), PubMed ($n = 45$), ScienceDirect ($n = 379$) and Scopus ($n = 66$)] were screened. Finally, six studies were included in the systematic review. In addition, three studies were enrolled in the meta-analysis.

3.2. Study characteristics

All studies focused on the post-operative rehabilitation of TKA patients (Bäcker et al., 2021; Crawford et al., 2021; Hardt et al., 2018; Huang et al., 2017; Timmers et al., 2019; Tripuraneni et al., 2021). Four papers used hardware (smartwatch, knee joint strengthening and training apparatus) associated with the mobile application (Bäcker et al., 2021; Crawford et al., 2021; Hardt et al., 2018; Tripuraneni et al., 2021). Only one study specifically and solely (in terms of hypothesis) focused on the app and device-mediated muscle training (Hardt et al., 2018). All other studies focused on the effectiveness of providing comprehensive rehabilitation, education and care practices with telerehabilitation (Bäcker et al., 2021; Crawford et al., 2021; Hardt et al., 2018; Huang et al., 2017; Timmers et al., 2019; Tripuraneni et al., 2021). Most (five) studies evaluated objective and subjective knee function with a ROM (Bäcker et al., 2021; Crawford et al., 2021; Hardt et al., 2018; Huang et al., 2017; Tripuraneni et al., 2021) and KOOS (Bäcker et al., 2021; Crawford et al., 2021; Hardt et al., 2018; Timmers et al., 2019; Tripuraneni et al., 2021), respectively. Only two studies performed function assessment with Knee Society Score (KSS) (Bäcker et al., 2021; Hardt et al., 2018). Half of the studies assessed pain with the Visual Analog Scale (VAS) (Bäcker et al., 2021; Hardt et al., 2018; Timmers et al., 2019) and quality of life with the EuroQol five-dimensional (EQ-5D) (Crawford et al., 2021; Timmers et al., 2019; Tripuraneni et al., 2021). Two studies evaluated psychological dimensions (e.g., satisfaction, participation) of the rehabilitation outcomes (Huang et al., 2017; Timmers et al., 2019). Three studies focused on physical performance with a Timed Up and Go Test (TUG), 10 Meter Walk Test (10MWT), 30-second Single Leg Stance (30s-SLS), 30-Second Chair Stand Test (30s-CST) (Bäcker et al., 2021; Crawford et al., 2021; Hardt et al., 2018). Only two studies addressed manipulation under anesthesia (MUA) assessment (Crawford et al., 2021; Tripuraneni et al., 2021).

3.3. Quality analysis and bias risk results

PEDro scores ranged from 4 to 7 (median: 5.5), indicating fair to good quality (Table 2). Six studies were in the "fair" and "good" class (Bäcker et al., 2021; Crawford et al., 2021; Hardt et al., 2018; Huang et al., 2017; Timmers et al., 2019; Tripuraneni et al., 2021). All studies were not used blinding (items 5, 6 and 7) (Bäcker et al., 2021; Crawford

Table 1
The summary of the included trials.

Trial	Objective	Disease of the Sample	Age	Interventions	Outcomes	Results
Huang et al. (2017)	Demonstrate the effectiveness of mobile application during the patient education	Patients following TKA	62.5	**Application Group** Functional exercises and patient education/monitorization with a mobile application **Control Group** Face to face rehabilitation and telephone-based education	**ROM** Active **Psychological** Satisfaction, compliance	The application group was yielded better results on ROM, satisfaction and compliance ($p<0.05$)
Hardt et al. (2018)	Evaluate the effect of application-based muscle training program	Primary TKA patients	65.9	**Intervention Group** **(1)** Active and passive ROM, gait education, muscle strengthening, stair climbing education, cold therapy and lymph massage **(2)** GenuSport device and app based active knee extension training **Control Group** Active and passive ROM, gait education, muscle strengthening, stair climbing education, cold therapy and lymph massage	**ROM** Active and passive **Pain-VAS** At rest and in motion **Knee strength** Extension strength by GenuSport **Performance** TUG, 10MWT, 30s-CST **Function** KOOS, KSS *Patients were followed up to the discharge	The active ROM improvement of the IG was better ($p<0.05$). Training group yielded better results in terms of pain at rest and in motion ($p<0.05$). 10MWT results was better in IG ($p<0.05$). KOOS and KSS scores of the IG was better ($p<0.05$)
Timmers et al. (2019)	Prove the effectiveness of application-based post-operative care	Primary unilateral TKA patients	**IG:** 64.7 **CG:** 65.3	**Intervention Group** Post-operative care, including multimedia sources **Control Group** Basic information two times per week related to the post-operation	**Pain-VAS** At rest, during activity and in motion **Function** KOOS **QoL** EQ-5D-3L **VAS** Exercises, self-care, satisfaction, involvement, consumption	The IG was yielded better results in all outcomes at four weeks ($p<0.05$)
Bäcker et al. (2021)	Prove the long-term effect of application-based post-operative rehabilitation	Primary TKA patients	64.3	**Intervention Group** **(1)** Active and passive ROM, gait education, muscle strengthening, stair climbing education, cold therapy and lymph massage **(2)** GenuSport device and app based active knee extension training **Control Group** Active and passive ROM, gait education, muscle strengthening, stair climbing education, cold therapy and lymph massage	**ROM** Active and passive **Pain-VAS** At rest and in motion **Knee strength** Extension strength by GenuSport **Performance** 10MWT **Function** KOOS, KSS	The IG yielded better results in pain, 10MWT, KSS function score at 2 years follow up ($p<0.05$). Less painkiller usage and more likely to participate in sports were observed in IG ($p<0.05$)
Crawford et al. (2021)	Demonstrate the effect of app-based exercise/ care	Primary total and partial knee arthroplasty patients	>18 years	**Intervention Group** Smartphone and smartwatch-based exercise and education intervention **Control Group** Formal physiotherapy sessions with a conventional post-operative rehabilitation	**ROM** Active and passive **QoL** EQ-5D-5L **Function** KOOS JR **Performance** TUG, 30s-SLS, MUA	In the 90-day follow-up, there was no significant difference between the two groups in terms of flexion ROM, 30s-SLS, and TUG ($p>0.05$). In the KOOS JR score, the CG functioned significantly better ($p<0.05$). The IG gave better results in terms of need for emergency visit and physiotherapy ($p<0.05$).
Tripuraneni et al. (2021)	Prove the effect of smartwatch paired and mobile application-based rehabilitation	Primary TKA patients	>18 years	**Intervention Group** The app was used in combination with the Apple Watch, including a 2-week pre-operative exercise followed by a 6-week post-operative protocol **Control Group** Formal physiotherapy sessions with a conventional post-operative rehabilitation	**ROM** Active **QoL** EQ-5D-5L **Function** KOOS JR **Performance** MUA * post-op 1 month, 3 months, 6 months, and 12 months	The KOOS JR score was lower in the IG than the CG at 3 and 6 months ($p<0.05$). However, this change did not meet the KOOS JR threshold of 8.02 units for minimal clinically significant difference.

ROM: Range of Motion, **VAS:** Visual analogue scale, **TUG:** Timed Up and Go, **30s-CST:** 30-second Chair Stand Test, **10MWT:** 10-minute Walk Test, **KOOS:** Knee Injury and Osteoarthritis Outcome Score, **KSS:** Knee Society Score, **EQ-5D:** EuroQol-5 Dimension, **30s-SLS:** 30-second Single Leg Stance, **MUA:** Manipulation Under Anesthesia, **IG:** Intervention Group, **CG:** Control Group.

Table 2
PEDro scores of the included trials.

Article	Q-1	Q-2	Q-3	Q-4	Q-5	Q-6	Q-7	Q-8	Q-9	Q-10	Q-11	Total
Huang et al. (2017)	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6
Hardt et al. (2018)	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	7
Timmers et al. (2019)	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6
Bäcker et al. (2021)	Y	Y	Y	Y	N	N	N	N	N	Y	N	4
Crawford et al. (2021)	Y	Y	N	Y	N	N	N	N	Y	Y	Y	5
Tripuraneni et al. (2021)	Y	Y	Y	Y	N	N	N	N	N	Y	Y	5
Total	6	6	3	6	0	0	0	3	4	6	5	

"Q-1: Eligibility criteria; Q-2: Random allocation; Q-3: Concealed allocation; Q-4: Baseline comparability; Q-5: Blind subjects; Q-6: Blind therapists; Q-7: Blind assessors; Q-8: Adequate follow-up; Q-9: Intention-to-treat analysis; Q-10: Between-group comparisons; Q-11: Point estimates and variability".

et al., 2021; Hardt et al., 2018; Huang et al., 2017; Timmers et al., 2019; Tripuraneni et al., 2021). All studies presented adequate data on "eligibility and randomization" (Bäcker et al., 2021; Crawford et al., 2021; Hardt et al., 2018; Huang et al., 2017; Timmers et al., 2019; Tripuraneni et al., 2021). Three studies did not mention the randomization allocation (Crawford et al., 2021; Huang et al., 2017; Timmers et al., 2019) and the detailed follow-up (Bäcker et al., 2021; Crawford et al., 2021; Tripuraneni et al., 2021) process. Two studies did not address the intention to treat analysis (Bäcker et al., 2021; Tripuraneni et al., 2021). Most (five) studies provide details on point estimates and variability of the data (Crawford et al., 2021; Hardt et al., 2018; Huang et al., 2017; Timmers et al., 2019; Tripuraneni et al., 2021).

All studies were classified as "some concerns" in RoB2 (Figs. 2 and 3) (Bäcker et al., 2021; Crawford et al., 2021; Hardt et al., 2018; Huang et al., 2017; Timmers et al., 2019; Tripuraneni et al., 2021). Domain 2 ("bias due to deviations from the intended interventions") and 5 ("selection of the reported result") are classified as "some concerns" in all articles (Bäcker et al., 2021; Crawford et al., 2021; Hardt et al., 2018; Huang et al., 2017; Timmers et al., 2019; Tripuraneni et al., 2021). In domain 1 ("bias arising from the randomization process") and 3 ("bias due to missing outcome data"), all studies had a low risk of bias (Bäcker et al., 2021; Crawford et al., 2021; Hardt et al., 2018; Huang et al., 2017; Timmers et al., 2019; Tripuraneni et al., 2021). For domain 4 ("bias in measurement of the outcome"), 3 of the studies were in the "some concerns" (Hardt et al., 2018; Huang et al., 2017; Timmers et al., 2019), and the other three were in the "high risk" class (Bäcker et al., 2021; Crawford et al., 2021; Tripuraneni et al., 2021).

3.4. Narrative synthesis results

The hypotheses of all studies questioned whether mobile applications could be applied as an alternative option rather than superior to conventional methods (Bäcker et al., 2021; Crawford et al., 2021; Hardt et al., 2018; Huang et al., 2017; Timmers et al., 2019; Tripuraneni et al., 2021). Two studies emphasized the advantage of mobile application-based telerehabilitation regarding ROM at 1-month follow-up (Huang et al., 2017) and discharge (Hardt et al., 2018), respectively. Three studies reported no difference between the mobile application-based and conventional rehabilitation groups in ROM for three months (Crawford et al., 2021), two years (Bäcker et al., 2021) and one year (Tripuraneni et al., 2021), respectively. Mobile application-based telerehabilitation provided better pain improvement at discharge (Hardt et al., 2018), one month (Timmers et al., 2019) and two years (Bäcker et al., 2021), respectively. Telerehabilitation had no additional positive effect on muscle strength at discharge (Hardt et al., 2018) and two-year follow-up (Bäcker et al., 2021).

The advantage of mobile application-based telerehabilitation was emphasized in a 3-month follow-up with the EQ-5D-3 L in quality-of-life evaluation (Timmers et al., 2019). However, no significant difference was noted with the EQ-5D-5 L at 3-month (Crawford et al., 2021) and 1-year (Tripuraneni et al., 2021). Two studies reported positive results regarding 10MWT at discharge (Hardt et al., 2018) and 2-year (Bäcker et al., 2021) follow-up in favor of mobile application-based applications. The two studies reported no significant difference between groups for TUG at discharge (Hardt et al., 2018) and 3-month (Crawford et al., 2021) follow-up. No difference was reported between the two groups at discharge for the 30s-CST (Hardt et al., 2018). Similarly, there was no difference between the groups in the 3-month follow-up results for the 30s-SLS (Crawford et al., 2021).

The mobile application group showed better results on KOOS at discharge and 1-month follow-up (Timmers et al., 2019). However, the other study did not report a significant difference between mobile application-based and conventional rehabilitation at a 2-year follow-up (Bäcker et al., 2021). One study reported positive results at 3–6 months follow-up in KOOS JR (Tripuraneni et al., 2021). The other study emphasized that the conventional rehabilitation group achieved better

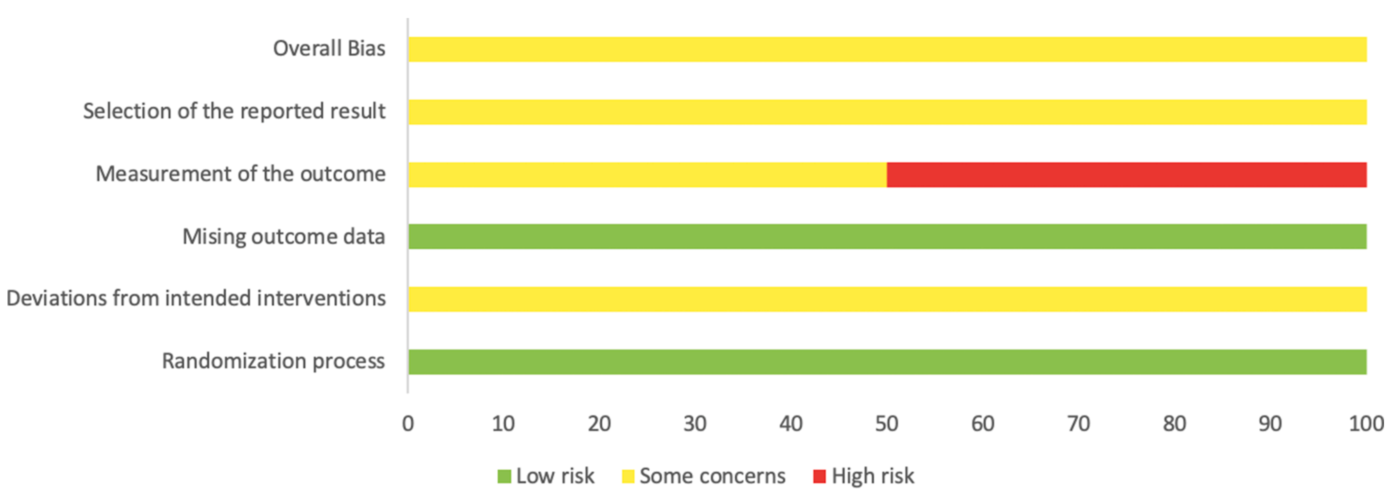

Fig. 2. Summary plot of the bias risk.

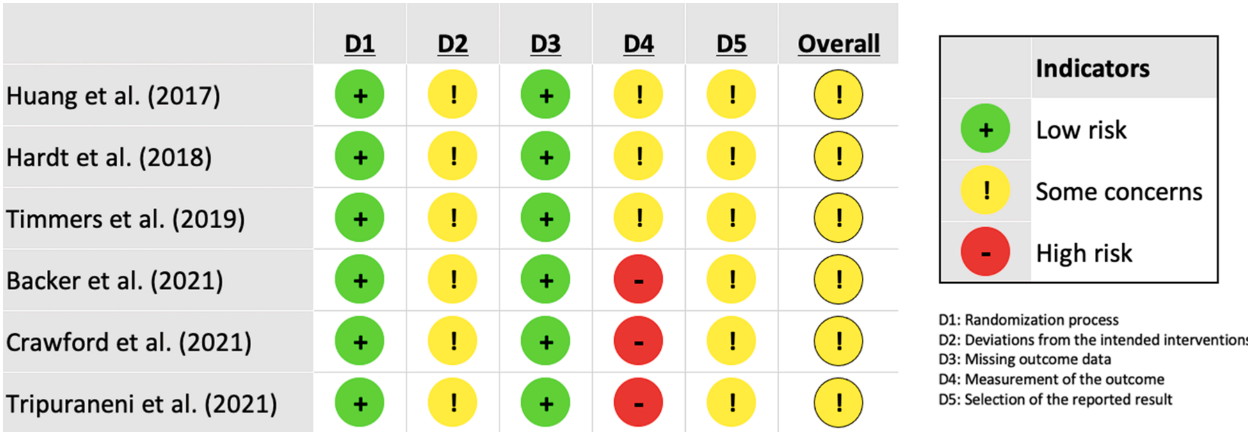

Fig. 3. Traffic-light plot of the bias risk.

results in KOOS JR (Crawford et al., 2021). Two studies indicated that KSS showed better results in favor of the mobile application-based rehabilitation group at discharge (Hardt et al., 2018) and 2-year (Bäcker et al., 2021) follow up.

One study emphasized the importance of mobile application-based rehabilitation in patient satisfaction and compliance at a one-month follow-up (Huang et al., 2017). Furthermore, one study highlighted more effective results of mobile application-based rehabilitation on participation, self-care, and quality of life in a one-month follow-up (Timmers et al., 2019). In a two-year follow-up study (Bäcker et al., 2021), the mobile application-based rehabilitation group showed better results regarding less analgesic use and more participation in sports. Finally, one study remarked that fewer emergency admissions and physiotherapy needs were lower in the mobile application-based rehabilitation group at 3-month follow-up (Crawford et al., 2021).

3.5. Meta-analysis results

Two studies were pooled for KOOS JR at 1-month follow-up (Tables 3 and 4) (Figs. 4 and 5). The results showed the superiority of mobile application-based rehabilitation over conventional practices (ES: 0.57, 95%CI: 0.11–1.02). On the other hand, in the pooling for active ROM, the results did not demonstrate the superiority of mobile application-based telerehabilitation (ES: 0.24, 95% CI: −0.31–0.79).

4. Discussion

This systematic review and meta-analysis purposed to demonstrate the effectiveness of mobile application-based rehabilitation in patients with TKA. According to the results, mobile application-based telerehabilitation provided more effective results than conventional rehabilitation in function, pain, and ROM. The quantitative analysis outcomes demonstrated the superiority of the mobile application-based function at a one-month follow-up.

Telerehabilitation provides pragmatic and practical results regarding both cost and clinical outcomes. Continuity in rehabilitation and correct implementation of exercises/lifelong habits are efficient with telerehabilitation technologies. (Buckingham et al., 2022; Chen et al., 2021; Gunter et al., 2016; Marzano et al., 2017; Özden et al., 2021; Pronk et al., 2020; Scheper et al., 2019; Zotov et al., 2020). Mobile application-based telerehabilitation has been popular in orthopaedics and traumatology (e.g., ROM measurement, post-operative care, pre-operative rehabilitation, wound care) in the last decade. The effectiveness of mobile-based rehabilitation applications has been investigated in pilot studies, feasibility research, quasi-experimental trials or randomized controlled studies (Bäcker et al., 2021; Crawford et al., 2021; Hardt et al., 2018; Huang et al., 2017; Ramkumar et al., 2019; Timmers et al., 2019; Tripuraneni et al., 2021).

This review discussed randomized controlled trials on the efficacy of mobile application-based telerehabilitation. Four studies used hardware in addition to the mobile application (Bäcker et al., 2021; Crawford et al., 2021; Hardt et al., 2018; Tripuraneni et al., 2021). Hardware requirements of mobile applications may be questionable for widespread impact due to economic problems (Brennan et al., 2009). Accessibility to a smartwatch or knee joint training device reduces the ease of use of some mobile app-based rehabilitation services. On the other hand, most (five) studies used KOOS, which is frequently used and accepted as the gold standard tool (Peer & Lane, 2013). However, considering that the new version of the Knee Society Score (KSS) is a more specific tool with expectation and satisfaction dimensions, it may be significant to be preferred in telerehabilitation studies (Scuderi et al., 2012). In addition, psychosocial parameters (kinesiophobia, fear of falling, depression and anxiety) were not addressed in any study. Future studies may focus on psychological parameters in addition to physical function (Lindner et al., 2018).

The methodological quality of the studies was "fair" and "good". None of the studies used blinding, which may increase the likelihood of biased results. "Consolidated Standards for Reporting of Trials" also points out the importance of randomization, intention-to-treat analysis and appropriate follow-up, which were not presented in some studies (Schulz et al., 2010). The bias risk of all studies was classified as "some concerns", probably due to the lack of blinding in all studies. Further studies should consider a patient, clinician, and assessor-blinded design (Sterne et al., 2019).

Table 3
Meta-analysis of KOOS JR score at 1 month.

Study name	Intervention n	Mean	SD	Control n	Mean	SD	Weight	Random, 95 %CI
Timmers et al. (2019)	114	−8.3	9.20	99	−0.75	9.42	48.1%	0.14 (0.52–1.08)
Tripuraneni et al. (2021)	153	12.1	9.95	184	15.6	10.35	51.8%	0.10 (0.12–0.55)
Total (95 %CI)	**267**			**283**			**100.0%**	0.23 (0.11–1.02)

Heterogenity: Tau^2=0.092, Chi^2=6.69, df=1; I^2=85.1%, **Overall effect:** Z=2.44 (p=0.01), **SMD:** 0.57.
SMD: Standardized Mean Difference, **n:** Number of Cases, **SD:** Standard Deviation, **CI:** Confidence Interval.

Table 4
Meta-analysis of active ROM score at 1 month.

Study name	Intervention n	Mean	SD	Control n	Mean	SD	Weight	Random, 95 %CI
Huang et al. (2017)	30	−2.15	5.84	102	−0.83	5.21	45.0%	0.20 (0.14–0.96)
Tripuraneni et al. (2021)	153	−11.7	17.6	184	−12.0	18.3	54.9%	0.10 (−0.23–0.19)
Total (95 %CI)	**183**			**286**			**100.0%**	0.28 (−0.31–0.79)

Heterogenity: Tau^2=0.134, Chi^2=5.83, df=1; I^2=82.8%, **Overall effect:** Z=0.847 (p=0.39), **SMD:** 0.24.
SMD: Standardized Mean Difference, **n:** Number of Cases, **SD:** Standard Deviation, **CI:** Confidence Interval.

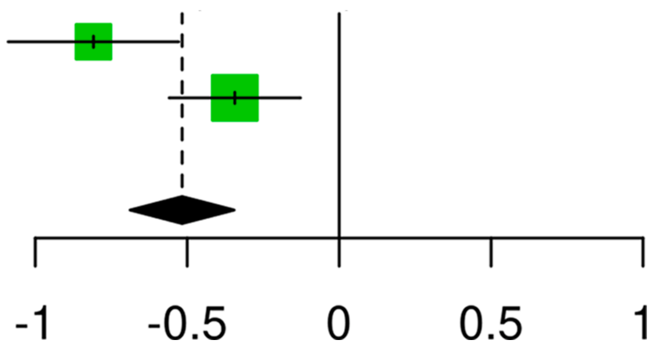

Fig. 4. Forest-plot of the KOOS JR score at 1 month.
CI: Confidence Interval.

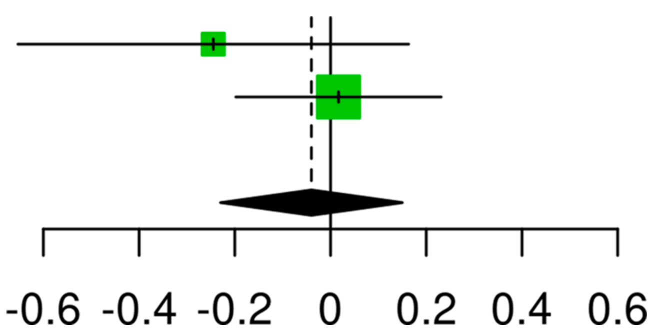

Fig. 5. Forest-plot of active ROM score at 1 month.
CI: Confidence Interval.

The ROM results of the included trials differ. Two studies (Hardt et al., 2018; Huang et al., 2017) pointed out the positive effect of mobile application-based rehabilitation at discharge and 1 month. However, three studies (Bäcker et al., 2021; Crawford et al., 2021; Tripuraneni et al., 2021) studies emphasized no additional effect of telerehabilitation in the long term. ROM is generally measured with a goniometer and inclinometer (Santos et al., 2012). The measurement protocol should require precise and calibrated occasions. A single and blind evaluator is critical during this sensitive measurement.

Another essential outcome was pain. Mobile application-based rehabilitation was effective on short, medium and long-term pain. According to the fear-avoidance model, pain is a psychological parameter (Leeuw et al., 2007; Vlaeyen et al., 2016). Patient-clinician communication advantage of telerehabilitation might provide additional psychological support for pain management. Remote education on symptoms might also positively affect the pain status of the individuals.

Regarding muscle strength, no difference between mobile application-based and conventional rehabilitation groups (Bäcker et al., 2021; Hardt et al., 2018). Both studies evaluated muscle strength with an external device. Therefore, measurements were possibly conducted with minimal bias. Although mobile application-based rehabilitation is not superior, it would be pragmatic to consider the results as an alternative to conventional rehabilitation.

Quality of life outcomes of the trials varied. The additional positive effect of application-based rehabilitation is not reported in the long term (Tripuraneni et al., 2021). However, mobile application-based telerehabilitation has positive quality-of-life outcomes in the medium term (Timmers et al., 2019). Future studies could holistically address the different dimensions of quality of life (expectancy, satisfaction, improved functional activities) with the new KSS (Scuderi et al., 2012).

Physical performance tests are an essential clinical indicator in post-op TKA. The performance in gait-based tests was increased in the mobile application-based telerehabilitation group (Bäcker et al., 2021; Hardt et al., 2018). However, mobile application-based rehabilitation did not provide additional improvement in terms of sitting-standing, short--distance walking and other performance tests related to balance (Tripuraneni et al., 2021). This different outcome in performance tests may have been due to heterogeneous study designs.

At the 1-month follow-up, the telerehabilitation group showed positive results for KOOS JR. However, mobile-application-based rehabilitation did not provide additional advantages for active ROM. In summary, meta-analysis results supported the importance of mobile-application-based rehabilitation on functional outcomes. As emphasized before, ROM evaluation might be presented with potential bias due to a lack of blinding in all studies (Schulz et al., 2010).

Apart from the randomized control studies in the literature, the clinical implications of other studies on the mobile application after TKA should also be considered. A recent qualitative study emphasized that more than half of the older individuals after arthroplasty comprehend the benefit of mobile applications. In addition, patients with higher technical knowledge use mobile application tools more effectively (Joshi et al., 2022). Another pilot study delivering a post-operative rehabilitation protocol via a mobile device reported efficient adherence to a telerehabilitation program combining exercise and medication management (Kim et al., 2016). Two recent articles also addressed the efficacy of mobile application-based pain management (Buck et al., 2021; Pronk et al., 2020).

4.1. Mobile application usability

Usability is an essential technical parameter of mobile applications in healthcare. Although technological literacy is rapidly increasing in the general population, the use of mobile apps among older adults is not widespread (Bender et al., 2014). In order to increase the usability of mobile health, developers should design applications regarding the physiological (sensory, motor and cognitive) declines and needs of older adults (Morey et al., 2019).

The three main parameters of mobile app usability are ease of use, satisfaction and effectiveness (Or et al., 2022; Tao & Or, 2012). The target population's needs should be considered in developing a more practical application for all three parameters. Due to the decreased visual perception in older individuals, devices with larger screens, larger text and instructions accompanied by quickly distinguishable colored figures can increase usability. Applications with "sound optimization" can help individuals with hearing loss problems. The button, scrolling, and touch features can be designed regarding the decreased fine motor function of the individuals. Applications should also be cognitively appropriate for older users. Fast transitions and complex design may reduce usability. Reminders, easy access to the clinician, and live-support features can further increase satisfaction in terms of usability (Morey et al., 2019).

This meta-analysis highlights the lack of randomized controlled trials on the usability of mobile applications. Recent research result revealed that the most critical parameter for mobile application usability is "satisfaction" (Patel & Thind, 2020). Future pilot feasibility studies will be beneficial in assessing the satisfaction of mobile health applications (Joshi et al., 2022).

On the other hand, although there is a standardized tool to evaluate mobile application usability, researchers generally did not prefer using these questionnaires. Specific patient-reported outcomes (e.g., mHealth App Usability Questionnaire, Telehealth Usability Questionnaire) can further strengthen the effectiveness analyses of mobile tools regarding usability (Özden et al., 2021; Zhao et al., 2019).

4.2. Limitations and strengths of the review

Some databases (e.g., CINAHL, EMBASE) could not be searched due to access. The results should be handled and discussed in terms of surgical techniques. One of the eligibility criteria indicated the inclusion of solely "randomized controlled" design trials. Therefore, both systematic review synthesis and meta-analysis pooling analysis results provided more homogeneous clinical outcomes.

4.3. Clinical implications

Rehabilitation in geriatric individuals after TKA is effective in pain management and functional improvement. Patients' continuity to protocols is essential for effective rehabilitation (Chen & Or, 2021; Dionisi et al., 2021). Therefore, mobile application-based rehabilitation would provide an essential health service to improve clinical and psychological parameters. Considering that mobile applications can also reduce possible health costs (Colomina et al., 2021), we predict that mobile application-based provides an alternative and pragmatic orthopedic rehabilitation service to conventional rehabilitation applications.

4.4. Conclusions

Compared to conventional rehabilitation, application-based telerehabilitation provides more effective results in function, pain and ROM. Furthermore, mobile application-based rehabilitation should also be considered regarding patient satisfaction and compliance.

Ethical approval

Not applicable.

CRediT authorship contribution statement

Fatih Özden: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Zübeyir Sarı:** .

Declaration of Competing Interest

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Supplementary materials

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