Review

Surface Electromyography as a Remote Monitoring and Biofeedback Tool for Quadriceps Reactivation Post Robot-Assisted Total Knee Arthroplasty: A Scoping Review of Protocols, Technologies, and Outcomes

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Abstract

Background: Use of robotics in total knee arthroplasty (raTKA) is well known, and has shown better results. However, neurogenic muscle inhibition and inability to voluntarily activate the quadriceps muscle are the key challenges of raTKA, leading to functional disability. Furthermore, the use of surface electromyography (sEMG) helps quantify the neuromuscular activity of muscles in real time. sEMG, when coupled with biofeedback and remote monitoring technologies, can efficiently predict quadriceps reactivation during home-based rehabilitation.

Objective: To identify and map existing evidence on the role of sEMG in remote monitoring and biofeedback for quadriceps activation following total knee arthroplasty (TKA) and robotic-assisted total knee arthroplasty (raTKA), and to generate protocols for future trials.

Methods: The scoping review was framed following the JBI methodology (Peters et al., 2021) and foundational guidelines given by Arksey and O'Malley and Levac et al. (2005). Screening of records and data charting was done by two reviewers using a piloted charting form. The scoping review is narrative and descriptive in nature. No critical appraisal was performed.

Results: The review consists of four parallel domains: (i) quadriceps dysfunction and AMI after TKA; (ii) early functional improvements with raTKA (including earlier straight-leg raise and earlier quadriceps reactivation); (iii) sEMG-based biofeedback training to improve quadriceps strength, activation, and functionality after all forms of knee surgery, with varied outcomes for TKA; and (iv) telerehabilitation and remote-monitoring systems with high engagement and non-inferior outcomes after TKA. There is an adjunct to literature where researchers has combined raTKA patients, sEMG monitoring at home, and quadriceps-specific outcomes within a closed-loop biofeedback protocol.

Conclusions: Converging but fragmented evidence supports the use of sEMG for remote monitoring and biofeedback of quadriceps reactivation following TKA, and raTKA provides a platform for standardised TKA surgery to test these digital innovations. Standardised protocol (including SENIAM; normalised amplitudes; defined feedback targets and a core outcome set) is needed to inform pragmatic randomised trials that determine efficacy, cost-effectiveness and scalability.

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Keywords. Surface electromyography; biofeedback; telerehabilitation; remote monitoring; robot-assisted total knee arthroplasty.

Introduction

The end-stage knee osteoarthritis is one of the major causes of disability worldwide, with a projected rate of 60%- 100% by 2050 (Courties et al. 2024). Total knee arthroplasty (TKA) is the preferred approach to treat end-stage OA (Inacio et al. 2017). Though TKA is a reliable way to reduce pain, not all patients achieve the desired levels of strength and functional performance.(Inacio et al. 2017). According to Mizner et al. (2003), quadriceps femoris weakness is a chronic issue following TKA, characterized by reduced voluntary activation, which can further induce arthrokinematic changes in the joint and lead to implant failure. Not only quadriceps strength but the synchronized activation of quadriceps and hamstrings is also altered which further delays patient's recovery (Stevens-Lapsley et al., 2010). Body mass index, age and gender can also plays a critical role in early gain of functionality post operation (Paravlic et al., 2022). Arthrogenic muscle inhibition (AMI) is due to altered afferent input from damaged and inflamed peri-articular tissues, but also involves spinal reflex pathways, and in the chronic phase, motor cortex excitability continuous reflex that impairs the central nervous system's ability to fully activate the quadriceps(Rice et al., 2014).

Robotics is used for pre-operative imaging, dynamic soft-tissue balancing, and haptic or semi-autonomous bone resection are in robot-Assisted TKA systems (e.g., Mako, ROSA Knee, NAVIO/CORI) to enhance the positioning of the implants (Held et al., 2023; Kayani et al., 2018. A prospective cohort study by Kayani et al. (2018) showed that raTKA, compared to traditional TKA, was linked to less pain, reduced opioid usage, early mobilization and discharge with better ROM of the Knee. Lesser post-operative swelling, quicker quadriceps reactivation, and earlier discharge were reported in the major platforms with raTKA compared to conventional robotic systems (Held et al., 2023).

Surface EMG is non-invasive procedure which provide real-time muscle activation (Yang et al., 2023). It can also be used as biofeedback device to re-train muscle activation, simultaneously can measure side-to-side asymmetry, and provide quantified progress to patient and clinician (Wasielewski et al., 2011). Karaborklu Argut et al. (2022) has summarised eight randomised controlled trials and found that EMG biofeedback was better than standard care at enhancing quadriceps strength and activation. One study has compared sEMG biofeedback to NMES post-TKA and found it is more superior in improving strength, range of motion, function, and quality of life (Armshaw et al., 2024).

In this technological era, rehabilitation is also utilising digitalisation and advanced hyper-sensitive modalities. Telerehabilitation and remote-monitoring programs using smartphone, inertial measurement unit (IMU) and wearable sEMG technologies have been shown to be feasible with high patient adherence (Mobbs et al., 2023; Nuevo et al., 2024).

Review Questions

This scoping review sought to comprehensively map the evidence on the use of sEMG as a tool for remote monitoring and biofeedback to target quadriceps reactivation following TKA and raTKA. In particular, we wanted to answer four questions:

1.What sEMG protocols (electrodes, signal processing, normalisation, feedback thresholds) have been applied to reactivate the quadriceps after TKA or other type of knee surgery?

2.What hardware (form factors), software and connectivity have been used to provide sEMG biofeedback and remote monitoring, and how will they be used in raTKA?

3.What clinical, neuromuscular and patient-reported outcomes, as well as the feasibility, adherence and safety have been reported?

4.What research and implementation challenges need to be resolved to incorporate sEMG biofeedback for remote monitoring in raTKA?

Methodological justification

An overview of reviews would focus on effects in systematic reviews but would not include relevant primary evidence of device validation, engineering and feasibility studies, which is critical to our questions (Munn et al., 2018). So we chose a scoping review because we aim to systematically map and describe the extent of the evidence (regardless of the source), to clarify definitions of concepts, to describe different methods and technologies, and to identify gaps to guide a future trial (Peters et al., 2021). This choice was informed by the Right Review tool (Amog et al., 2022; Clyne et al., 2024) and is in accordance with the JBI definition of a scoping review (Munn et al., 2022; Peters et al., 2021).

Methods

Protocol, registration, and reporting

This scoping review was conducted using the JBI methodology for scoping reviews outlined by Peters et al. (2021), building on the work of Arksey and O'Malley (2005) and Levac et al. (2010).

Review team and knowledge users

In line with current JBI recommendations (Peters et al., 2021; Pollock et al., 2022), the review team consist of two reviewers from physiotherapy background. Knowledge users (two practicing physiotherapists were involved in refining the review questions, inclusion criteria, data-charting form, and the interpretation of the findings, consistent with the JBI co-creation approach (Pollock et al., 2022). This was to help ensure that the review's development, findings and implications were relevant to clinical practice and patients and that conclusions were not overreached (a known threat to conclusions derived from scoping reviews (Pollock et al., 2024)).

Eligibility criteria (PCC)

Inclusion criteria were based on the JBI Population, Concept, Context (PCC) model (Peters et al., 2021) and questions.

Population: primary TKA (including raTKA) in adults aged ≥18. We included studies of unicompartmental arthroplasty or other (non-arthroplasty) knee surgery (for example, anterior cruciate ligament reconstruction or meniscectomy) as methodological references for sEMG protocols as few TKA-specific studies were available.

Concept: use of sEMG of quadriceps muscles (rectus femoris, vastus medialis, vastus lateralis, vastus intermedius) for monitoring, biofeedback or closed-loop sEMG-triggered NMES. Invasive EMG and diagnostic-only studies were excluded.

Setting: any rehabilitation setting (inpatient, outpatient, home, hybrid) and pre-operative, early (≤6 weeks), subacute (6 weeks - 6 months) and late (>6 months) post-operative time points.

Type of studies: randomised and non-randomised controlled, cohort, feasibility, registered protocol, systematic reviews, narrative reviews, engineering/device development/validation studies, and peer-reviewed conference proceedings. Editorials, case reports (n < 3) and non-English sources without abstracts in English were excluded. Studies of last 10-15 years were included.

Information sources

We searched nine literature databases from their inception to the date of the search: PubMed/MEDLINE, Embase, Scopus, Web of Science Core Collection, Cochrane Central Register of Controlled Trials (CENTRAL), CINAHL, IEEE Xplore, PEDro and Google Scholar (first 200 hits). We also searched two trial registries for ongoing trials: ClinicalTrials.gov and the WHO International Clinical Trials Registry Platform. All included studies and reviews were also checked for relevant references and forward citation searches were conducted in Web of Science and Google Scholar.

Search strategy

The information specialist developed the search strategy, with systematic consultation from content and methodological experts, and peer reviewed it using the Peer Review of Electronic Search Strategies (PRESS) checklist prior to use. The search strategy included four blocks, connected by Boolean operators: (i) surgical population (TKA, raTKA, synonyms), (ii) sEMG (synonyms), (iii) intervention or delivery (biofeedback, telerehabilitation, remote monitoring, wearables), and (iv) Quadriceps target. Searches included both controlled vocabulary (MeSH, Emtree, CINAHL Subject Headings) and free text with suitable truncation. The complete search strategies for each database, including a breakdown of syntax and numbers of hits, can be found in Supplement S2.

Source of evidence selection

Two reviewers independently screened the titles and abstracts of all records in duplicate against the eligibility criteria. The full texts of potentially relevant records were then screened in duplicate. Conflicts were resolved through discussion. Cohen's κ was calculated to determine inter-rater agreement at both steps, aiming for a κ of at least 0.70. Reasons for excluding full texts were documented and presented in the PRISMA-ScR flow diagram (Figure 1; Supplement S5).

Data charting

A structured data-charting form was developed a priori and synchronised with the review questions and the JBI charting recommendations (Peters et al., 2021; Pollock et al., 2023). The form was pilot-tested independently by two reviewers on a 10% random sample of sources, and refined to enhance reliability. Details extracted from the studies were: authors, publication year, country, and study design; age, sex, type of surgery and time since surgery; sEMG device and placement (with reference to SENIAM compliance (Hermens et al., 2000)); processing and normalisation method; biofeedback mode, dose, and frequency; remote-monitoring features and connectivity; comparators; outcome domains and outcome measures; duration of follow-up; and study limitations. The completed form is available in Supplement S3.

Critical appraisal of individual sources

In line with PRISMA-ScR (Tricco et al., 2018) and scoping reviews more generally (Peters et al., 2021) we did not conduct a formal risk-of-bias assessment. This choice is in line with the mapping nature of the review and the variety of sources included (such as engineering and device-validation studies, for which existing risk-of-bias tools are not tailored). However, we did describe characteristics important to interpretation (e.g., randomisation, blinding, sample size, reporting) to guide readers' assessment of the evidence base.

Synthesis and presentation

We have used narrative synthesis (Pollock et al., 2023). Data were tabulated, counted and frequencies calculated. Inductive qualitative content analysis was used to describe the components of sEMG protocols, types of biofeedback, and remote-monitoring functions. Evidences were gathered from four review questions (protocols, technologies, outcomes and implementation) in an evidence map (Table 1; Figure 2). Research findings are summarised with reference to the review purpose, with implications for future research and policies, in line with current guidance to prevent overstretched conclusions in scoping reviews (Pollock et al., 2024).

Results

Selection of evidence and characteristics of sources

Figure 1 illustrates the flow of records through the processes of identification, screening, eligibility and inclusion (PRISMA-ScR flow diagram, Supplement S5). The included sources were published mostly since 2010 and were diverse, including randomised controlled trials, prospective cohort studies, feasibility and pilot studies, engineering and methodological studies, systematic reviews and meta-analyses. They were predominantly published from Europe, North America and East Asia. Most TKA-specific sources reported cohorts of traditional approach; few reported raTKA-specific cohorts. See Supplement S4 for the characteristics-of-sources table.

Evidence map

The sources identified in the charted into four parallel streams of evidence that reflected the conceptual building blocks of the review (Figure 2):

Stream A -quadriceps dysfunction and AMI post TKA;

Stream B - raTKA and early functional recovery;
Stream C - sEMG biofeedback of quadriceps reactivation; and strea
Stream D - remote monitoring and telerehabilitation following TKA.

Importantly, none of the sources included talks about all four streams of research in the same integrated study - i.e. there was no study found that offered a combination of a raTKA cohort, home-based remote sEMG monitoring, closed-loop biofeedback, and quadriceps-specific neuromuscular outcomes. This is the main evidence gap the review has identified, summarised in Table 1.

Stream A - Quadriceps dysfunction and AMI after TKA

Mizner et al. (2003) have shown that muscle atrophy and reduced mobility are the drivers of quadriceps weakness following TKA and a follow up quantitative study has shown that atrophy and delayed early mobilization are responsible of about 85 percent of the quadriceps strength loss in one month post-surger. The review by Rice and McNair (2010) placed AMI as a presynaptic reflex inhibition caused by changes in afferent input due to damaged peri-articular tissue, followed by other modifications in motor cortex excitability due to post- op knee effusion (Rice et al., 2014). The recent meta-analysis by Paravlic et al. (2022) established that reduced quadriceps activity is the primary cause of weakness after a surgical procedure, rather than atrophy, BMI, sex, and age can increase the course of recovery. Stevens-Lapsley et al. (2010) stressed that it is vital to attenuate quadriceps activation deficits early to improve longer-term functionality, and the recent narrative review by Churchill et al. (2024) listed perioperative interventions to decrease AMI with NMES and voluntary contraction training becoming the most promising options.

Stream B -Robot-assisted TKA and early recovery

The prospective cohort study by Kayani et al. (2018) (n = 80; 40 raTKA v/s 40 conventional TKA) reported decreased post-operative pain, decreased opioid use, decreased time-to-first-straight-leg-raise, increased knee flexion at discharge, reduced inpatient physiotherapy sessions, and reduced . An identical group had a subsequent five-year follow-up study which demonstrated similar functional outcomes between groups in favour of raTKA (Kayani et al., 2023). The comparative analysis by Held et al. (2023) summarised the evidence in the existing robotic systems, outlining the accuracy of implant positioning improvement, the decreased swelling of the soft tissues, the time spent on quadriceps reactivation, and the discharge with raTKA. A study of NAVIO robot-assisted TKA with intensive rehabilitation programme was an observational study that reported improvements in flexion recovery and functional capacity at the short and medium term (Scaturro et al., 2023).

Stream C - sEMG biofeedback for quadriceps reactivation

Evidence base

The systematic review of EMG biofeedback of the quadriceps between orthopaedic knee populations by Wasielewski et al. (2011) indicated that EMG biofeedback resulted in clinically meaningful effects on the quadriceps activation and functioning after arthroscopic meniscectomy and reconstruction of the anterior cruciate ligament. Karaborklu Argut et al. (2022) studied eight randomised trials of EMG biofeedback following orthopaedic knee surgeries (PEDro scores 68) and found that most studies reported EMG biofeedback to be better than usual care, home exercises or electrical stimulation in terms of quadriceps strength and activation with inconsistent effects on range of motion. The meta-analysis of six trials conducted by Xie et al. (2021) on knee surgery surgeries indicated statistically significant positive effect on knee range of motion in favour of EMG biofeedback (SMD -0.48; 95% CI -0.82 to -0.14) and suggested the use of EMG biofeedback as an addition to standard rehabilitation following knee surgery.

Armshaw et al. (2024) found that sEMG biofeedback has advantages over NMES after TKA with individualized adaptive thresholds and that the dose and individualization of biofeedback were at least as important as its presence. Christanell et al. (2012), randomised 16 patients with or without EMG biofeedback to vastus medialis in the early post-operative period and found better knee extension and integrated EMG (iEMG) in the biofeedback group, demonstrating that biofeedback can modify the neuromuscular recovery trajectories in small samples.

Protocol characteristics

There was convergence and heterogeneity of protocols across included biofeedback sources. The most frequently used target muscles were vastus medialis (often the vastus medialis oblique), then vastus lateralis and rectus femoris; multi-channel experiments used all three heads. Electrode positions were done according to SENIAM protocols where they were reported (Hermens et al., 2000) but methodological studies by Finni and Cheng using MRI-verified locations revealed significant variability in lateral electrode positioning over vastus medialis and rectus femoris despite SENIAM being used, with cross-talk being especially susceptible in vastus lateralis when the electrodes Sampling rates were usually 1000-2000Hz, band-pass filters 20-450Hz + a 50/60Hz notch, and root-mean-square (RMS) windows 50-250ms. normalisation methods used included maximum voluntary isometric contraction (MVIC), sub-maximal isometric reference contractions (favored

Table 1. Evidence map across four streams: representative findings, key gaps, and implications for an integrated raTKA + remote sEMG biofeedback pathway.

Evidence stream	Representative findings	Key gaps	Implication for raTKA + remote sEMG
A. AMI after TKA	Activation failure ~2× atrophy contribution at one month; AMI persists for months to years (Mizner et al., 2003, 2005; Paravlic et al., 2022; Rice & McNair, 2010; Rice et al., 2014).	Rarely captured with sEMG in the home setting; limited biofeedback integration.	Remote sEMG can objectively track AMI trajectory in the early post-operative window.
B. raTKA early recovery	↓Pain, ↓opioids, shorter time to straight-leg raise, earlier discharge (Held et al., 2023; Kayani et al., 2018); medium-term differences attenuate (Kayani et al., 2023).	Rehabilitation protocols not yet tailored to the earlier reactivation window.	raTKA provides a standardised surgical platform for testing digital rehabilitation.
C. sEMG biofeedback	Reviews support improved strength, activation, and ROM (Giggins et al., 2013; Karaborklu Argut et al., 2022; Wasielewski et al., 2011; Xie et al., 2021); TKA RCTs mixed (Armshaw et al., 2024; Sklempe Kokic et al., 2022).	Protocol heterogeneity; mostly clinic-based; few raTKA-specific studies.	Harmonised protocols required before remote, raTKA-specific implementation.
D. Telerehabilitation	Non-inferior outcomes vs usual care; high adherence (Bolam et al., 2021; Correia et al., 2018; Mobbs et al., 2023; Nuevo et al., 2024; Ramkumar et al., 2019; Small et al., 2019; Zhai et al., 2025); wearable sEMG emerging (Hu et al., 2025; Plavoukou et al., 2025).	IMU-dominant; sEMG integration early; data-security and regulatory frameworks still maturing.	Technical substrate for the proposed integrated pathway exists and is maturing.

AMI, arthrogenic muscle inhibition; IMU, inertial measurement unit; raTKA, robot-assisted total knee arthroplasty; ROM, range of motion; sEMG, surface electromyography; TKA, total knee arthroplasty.

inferior or superior to standard care (Yang et al., 2023; Zhai et al., 2025).

The nearest analogue to the suggested integrated pathway is the KneE-PAD randomised controlled trial by Plavoukou et al. (2025), which implemented eight Delsys Trigno Avanti wireless wearable sensors that combine sEMG and IMU with avatar-based feedback to provide telerehabilitation to knee osteoarthritis patients, which showed significant differences between-group in quadriceps. It has also been reported that multimodal knee-osteoarthritis platforms with sEMG, pressure, and IMU signals have been used to provide intelligent home rehabilitation (Hu et al., 2025).

Outcomes reported across streams

The outcomes were reported in five categories, (a) neuromuscular (sEMG RMS, peak-to-peak, integrated EMG, median frequency, symmetry index, voluntary activation ratio); (b) strength and performance (isometric peak torque, rate of torque development Table 1 shows the mapping of the representative findings, gaps, and implications of the integrated raTKA + remote sEMG pathway.

management[9].Red flags mandating MRI are listed in Table 3.

7. Contemporary Management

The management algorithm for PT-BPPV is presented in Table 4. Multiple canalith repositioning procedure (CRP) sessions are the norm in PT-BPPV rather than the exception.

Discussion

Summary of evidence

This scoping review was a systematic mapping of the evidence of sEMG-based remote-monitoring and biofeedback techniques with regard to the quadriceps reactivation following TKA and raTKA. There are four findings that are outstanding. To start with, the neural problem with quadriceps weakness in the initial post-operative weeks is the only type of problem that can be quantified and re-trained non-invasively consecutively at the bedside or even at home with the use of sEMG (Mizner et al., 2003, 2005; Paravlic et al., 2022; Rice and McNair, Second, raTKA is linked to a

faster quadriceps reactivation, a reduced time to straight-leg raise, and an early discharge in relation to conventional TKA (Held et al., 2023; Kayani et al.,
), which forms a specific period of 2-6 post-operative weeks when a specific reactivation intervention can be particularly effective. Third, sEMG biofeedback has a credible evidence base including knee surgeries (Armshaw et al., 2024; Christanell et al., 2012; Giggins et al., 2013; Karaborklu Argut et al., 2022; Wasielewski et al., 2011; Xie et al., 2021). Fourth, clinical effectiveness and technical viability of telerehabilitation in the post-TKA period is well-established (Bolam et al., 2021; Correia et al., 2018; Mobbs et al., 2023; Nuevo et al., 2024; Ramkumar et al., 2019; Small et al., 2019; Zhai et al., 2025), existing platforms have revolutionized sensor based signal acquisition. The development of wearable multimodal systems that can record sEMG and IMU and pressure data concurrently in AI-enabled feedback platform can empower and facilitates the conceptual and practical design of an advanced remote rehabilitation paradigm (Hu et al., 2025; Plavoukou et al., 2025).

None of the studies has combined raTKA cohort with home-based wearable (like sEMG) and closed-loop biofeedback and structured quadriceps activation. The nearest existing analogue is the KneE-PAD pilot in knee osteoarthritis (Plavoukou et al., 2025), which demonstrates that wearable sEMG-based telerehabilitation can potentially lead to measurable improvements in the neuromuscular activity and functional mobility when compared to conventional physiotherapy. The logical next step is to translate this approach into the context of the raTKA post-operative environment, but is currently limited by the heterogeneity of the protocols and the lack of a central outcome set.

A three-layer integration framework

To transform this evidence into testable practice, we suggest an inductive three-layer framework of measurement, feedback, and monitoring which is the result of inductive analysis of the charted protocol and technology characteristics.

Measurement: Bipolar electrodes in compliance with SENIAM guidelines (at least 1 kHz sample, Bluetooth Low Energy to smartphone). Normalisation should be done with a sub-maximal reference contraction, during the first two weeks and during MVIC in the fourth to sixth weeks and semi-permanent skin marking should be used to preserve inter-session reproducibility (Finni and Cheng, 2009 Hermens et al., 2000).

Feedback: Real-time visual and optional auditory feedback with adaptive thresholds (baseline and progressive increments), reflected to a clinician dashboard. Avatar-guided or gamified interfaces will probably be able to maintain engagement (Plavoukou et al., 2025; Wasielewski et al., 2011). A fallback should be a closed-loop sEMG-triggered NMES that patients should be able to cross an activation threshold.

Monitoring and adaptation: Cloud synchronisation, compliance analytics, safety- alerting rules and scheduled synchronous video review at 2-, 6-, and 12-week milestones preserve the therapeutic alliance and provide objective remote oversight.

Methodological and implementation considerations

There are several factors that early post-operative sEMG acquisition must contend with, including oedema, dressings, haematoma and incision orientation, each of which influences placement and signal quality. Although the strict compliance with the MRI-proven data, substantial variability in lateral positioning over vastus medialis and rectus femoris was observed with the potential of cross-talk over vastus lateralis when electrodes were placed too close to the rectus femoris (Finni and Cheng, 2009; Hermens et al., 2000). Practical solutions such as palpation-assisted placement, semi-permanent skin marking, per-session reference contractions, and automated signal-quality checks (signal-to-noise ratio, electrode impedance, cross-talk indices) emerged in the patient on the paired smartphone prior to the start of recording.

The harmonised core outcome set, which spans neuromuscular, strength, functional, patient-reported and implementation domains is a precursor to pooled evidence. Proposed minimum components include quadriceps sEMG amplitude (RMS) and side-to-side symmetry index; isometric peak torque and rate of torque development; knee extension lag and straight-leg raise time (which can be directly compared with the raTKA cohort data (Kayani et al., 2018)); timed up-and-go and 30-second chair stand; KOOS, Forgotten Joint Score-12, and EQ-5D-5L; and adherence and time-on-device. Equity considerations - digital literacy, connectivity, visual or auditory impairment, and multilingual interfaces - and data-governance pathways under GDPR / HIPAA-equivalent frameworks must also be designed in as much as possible, and the feedback mechanisms of AI will also require explicit attention under Software-as-a-Medical-Device pathways.

Implications for practice and research

According to the present-day guidelines on the scoping review (Pollock et al., 2024), the implications below are presented as a research and policy direction and as descriptive observations that are relevant to the current practice; they cannot be read as recommendations of the clinical effectiveness.

Three observations are formed by the mapped evidence to clinicians. Following both TKA and raTKA, early mobilization, quantified quadriceps activation, range of motion and VAS, are initial goal of rehabilitation, although reactivation window appears to be considerably more permissive in the case of raTKA (Held et al., 2023; Kayani et al., 2018). Several systematic reviews support the use of sEMG biofeedback as an adjunct to standard rehabilitation (Giggins et al., 2013; Karaborklu Argut et al., 2022; Wasielewski et al., 2011; Xie et al., 2021). Adequately documented feasibility and compliance data in commercially available telerehabilitation platforms can be reasonable options when patients are unable to attend in-person physiotherapy (Bolam et al., 2021; Correia et al., 2018; Mobbs et al., 2023; Nuevo et al., 2024; Ramkumar et al., 2019; Small et al., 2019; Zhai et al., 2025).

In the case of researchers, a pragmatic, adequately powered randomised controlled trial comparing an integrated raTKA + wearable sEMG-biofeedback-enabled telerehabilitation against a standardised telerehabilitation comparator (IMU only) and a usual-care comparator. Design priorities consist of: stratification by baseline activation deficit; an intervention window of 12 weeks with at least 12-month follow-up; pre-registration; blinded outcome assessors of strength and performance measures; and embedded health-economic and implementation-science evaluation. Qualitative research within a group of patients and therapists will help to identify facilitators and barriers to continuous engagement with wearable sEMG at scale.

Strengths and limitations

The strengths of this review are that it uses a modern methodological framework (JBI, Peters et al. 2021), was peer-reviewed, and searched nine databases and two trial registries, which is also a JBI-recommended practice that we found valuable in framing review questions and avoiding overstretched conclusions (Peters et al., 2021; Pollock et al., 2022, 2024).

There are a number of restrictions that must be mentioned. First, it was not done as a formal critical review of risk of bias, and the certainty of evidence cannot therefore be inferred, and no quantitative pooling was done. Second, the literature on digital-health and raTKA is rapidly changing, and this review will need periodic updating; readers should consult registered trials to access the most up-to-date evidence. Third, without raTKA-specific sEMG research, there are a number of inferences made based on traditional TKA and adjacent knee-surgical cohorts; although these inferences are explicit and traceable, they remain inferences. Fourth, the presence of non-English sources with no abstracts that could be translated was used to filter out grey literature, thus potentially under-sampling regional evidence. Lastly, the fact that the pace of regulatory and connectivity standards applicable to medical wearable devices is so fast means that the considerations of implementation that have been summarised here need to be re-assessed against jurisdictional rules at the time of any future trial.

Conclusions

Post TKA and raTKA, quadriceps activation is a key for functionality and less post op complications. The objective way to measure the neuromuscular deficit is through surface EMG and it can help clinician achieve quantifiable results . The elements of an integrated sEMG-guided remote biofeedback pathway of quadriceps reactivation after raTKA are in isolation and have not been synthesised as a single pathway of care. The next steps that are required are harmonised protocols, a core outcome set, and pragmatic randomised controlled trials. This scoping review can help in creating framework for future studies.

Declarations

Ethics approval. Not applicable -this study used only published and registered evidence.

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Conflicts of interest. The authors declare no conflicts of interest .

Data availability. Search strategies, the charting form, and the extracted data will be made publicly available on acceptance.

Reporting standards. PRISMA-ScR 20-item checklist (Supplement S1).

Supplements

- S1 -PRISMA-ScR 20-item checklist.
- S2 -Full search strategies (all databases and registries).
- S3 -Data-charting form.
- S4 -Characteristics of included sources.

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