Total knee arthroplasty (TKA) is the gold standard of treatment for patients with end-stage arthritis of the knee. As of 2010, more than 620,000 TKA procedures were performed annually in the United States.¹ By 2030, this is predicted to reach 3.5 million annually.² Even with these high volumes, the 2003 National Institutes of Health consensus statement on TKA concluded that “the use of rehabilitation services is perhaps the most understudied aspect of the perioperative management of TKA patients . . . [and] there is no evidence supporting the generalized use of any specific pre-operative or post-operative rehabilitation intervention.”³ In response to this statement, investigators have reported on a plethora of rehabilitative techniques and regimens available for perioperative management of TKA patients. In the United States, rehabilitation after TKA refers to several different practice settings depending on the patient, the health care system, and treatment decisions made by both the health care team and the patient. “Rehabilitation” begins at or before entering the acute inpatient setting, where decisions are made concerning the most appropriate discharge location for the patient. Possible discharge locations for a patient after TKA are a skilled nursing facility, an inpatient rehabilitation facility, home with home health physical therapy, home with a prescribed home exercise program, or outpatient physical therapy.⁴ Müller et al⁵ observed that best practice in rehabilitation is largely based on clinical experience, local customs, anecdotal evidence, surgeon preferences, clinical pathways established for the acute-care phase of recovery, and health insurance funding schemes.

This review reports the numerous available rehabilitation options, highlights the regimens with the highest level of evidence-based consensus, and examines some burgeoning opportunities in rehabilitation that may be necessary to keep pace with the increasing demand for TKA.

**Materials and Methods**

**Search and Selection**

In May 2016, a thorough search was conducted of MEDLINE (from 1966), the Cochrane Library, and the Physiotherapy Evidence Database (PEDro). Included
were studies published in English, concerning perioperative interventions for primary TKA, with well-established outcomes, considered randomized controlled trials (RCTs), with a matched cohort, considered comparative retrospective case series, and considered applicable Cochrane reviews and meta-analyses. Excluded studies included those with data not reported, those with nonquantitative outcome measures, or those published prior to 1985. Search terms included total knee arthroplasty, physiotherapy, rehabilitation, management, preoperative, postoperative, continuous passive motion, telerehabilitation, in-home exercises, neuromuscular electric stimulation, diet, and Wii as isolated terms and in combination.

Data Analysis

For specific interventions that had sufficient data, a forest plot was constructed to analyze effectiveness. Only continuous passive motion (CPM) as an intervention had enough data in the existing literature to be analyzed. Any study since 1990 that had adequate reporting of data to analyze was included. Of the 28 studies found concerning CPM, 17 were included.6–22 Eleven studies were not included, mainly due to incomplete data reporting.23–34 Of the excluded studies, some did not report standard deviations, others did not use a standard protocol for the measurement of range of motion (ROM), and one was outside the date range specified in the inclusion criteria.

To generate the forest plots, the standardized mean differences between treatment groups on each outcome were calculated at each time point for which data were available, as well as 95% confidence intervals for these effects. These effect size estimates were then pooled across the subset of studies making the same treatment comparisons at the same time points using standard random effects meta-analytic methods. All analyses and plotting were accomplished using the rmmeta, meta, and es.compute libraries of the R statistical program (version 3.0.0; R Foundation) released in 2014.

**DISCUSSION**

**Preoperative Interventions**

**Preoperative Patient Education.** Preoperative education refers to any educational intervention delivered before surgery that aims to improve the patients’ knowledge, perspectives, health behaviors, and/or health outcomes.35–37 Although the content of preoperative education varies, it often includes discussion of administrative procedures, the surgical procedure, postoperative care, potential stressful scenarios, potential complications, pain management, and movements to perform or avoid after surgery.38

Chen et al39 randomized patients (n=92) to receive either a pamphlet or educational videos and a skill-teaching session for rehabilitation or usual standard care. Patients receiving the additional materials reported lower pain scores up to 2 days postoperatively; after that, the only significant differences were in stair climbing time, eating, and the regularity of performing straight-leg raises. Crowe and Henderson40 provided patients (n=133) with a 50-minute video, an informational booklet, a tour of the postoperative hospital unit, and a demonstration of how to use the postoperative equipment. Although they found that length of stay (LOS) could be reduced by offering comprehensive individualized educational materials for patients, they did not find significant differences in joint flexion, the 30-minute walking test, or stair climbing.40 Encompassing 12 similar studies (n=1567), a systematic review conducted in 2015 analyzed the effect of preoperative education on anxiety, pain, LOS, patient satisfaction, postoperative complications, mobility, and expectations. Among these outcomes, preoperative education was only found to be effective in reducing preoperative patient anxiety.41

Current evidence seems to indicate that a focus on preoperative education has little clinical benefit. Although preoperative education should remain a part of the clinical pathway in TKA, no extra resources or time apart from the standard of care seems to be indicated currently.

**Physiotherapy/Prehabilitation.** Preoperative physiotherapy or “prehabilitation,” whether in a home setting or a clinical setting, is theorized to improve postoperative TKA outcomes by increasing knee ROM and strengthening the quadriceps muscles before surgery. A graphical representation of this theory, similar to one presented by Ditmyer et al,42 is shown in **Figure 1**.

In 2007, Williamson et al43 (n=181) administered a 6-week course of preoperative physiotherapy that included “static quadriceps contractions, inner range quadriceps contractions, straight leg raises, sit-to-stands, stair climbing, calf stretches, theraband resisted knee extensions, wobble board balance training, knee flexion/extension sitting on gym ball, and free-standing pedal revolutions.” They found no significant differences in LOS, Oxford knee score, 50-minute walking test, visual analog scale score, or Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score. Mitchell et al44 conducted an RCT (n=160) comparing patients who received preoperative and postoperative physiotherapy with those who received only postoperative physiotherapy. Preoperative physiotherapy included pain relief, techniques to increase knee flexion and extension, gait reeducation, and functional adaptations.44 For all outcome measures, including WOMAC, stiffness, and Short Form-36 scores, the authors found no significant differences for patients receiving the extra preoperative physiotherapy.

Contrastingly, some studies have found significant short-term differences in postoperative outcomes when administering preoperative physiotherapy to TKA patients. In 2014, Matassi et al45 randomized patients (n=122) to either receive a preoperative 6-week home-based exercise program or continue normal activities until
surgery. With a 79% compliance rate with the at-home regimen, the authors concluded that preoperative home-based exercise offered a boon in short-term knee ROM, but had no significant effect on knee ROM or Knee Society score 1 year after TKA.45

Despite the body of evidence mounting against both preoperative education and preoperative physiotherapy individually, it was hypothesized that combining these interventions might offer superior postoperative outcomes in TKA. Beaupre et al46 randomized patients (n=131) to either a combined education/exercise program that consisted of 3 sessions for 4 weeks preoperatively or a control group that received usual care. They found no significant differences in ROM, pain, function, or health-related quality of life up to 1 year after TKA.46

Overall, recent reviews and meta-analyses unanimously agree that patient outcomes are not significantly affected in the long-term by preoperative physiotherapy regimens.47-49 Wallis and Taylor49 hypothesized that preoperative physiotherapy shows little effect because “it is possible that marked reduction of pain that comes from replacing painful joint surfaces during surgery far outweighs modest contribution from pre-operative interventions.” An alternative hypothesis is that patients are so significantly deconditioned from the surgery that any benefits gained from preoperative rehabilitation are muted.50 The revised model for the effects of preoperative physiotherapy is shown in Figure 2. Currently, preoperative rehabilitation is rarely prescribed by surgeons because of the lack of long-term postoperative benefits.51

Short-term Postoperative Interventions

**Inpatient Rehabilitation.** Inpatient rehabilitation refers to any intervention that follows immediately after TKA and prior to initial discharge. Although there is large consensus on the importance of a rehabilitation regimen immediately following TKA, little agreement exists on the exercises that comprise the regimen, the intensity of exercises, and the duration. Recent regimens reported in the literature vary in duration from 3 to 14 days and have employed interventions such as walking, stretching, gait retraining, CPM, aquatic therapy, quadriceps strengthening exercises, and stair climbing exercises. Contemporary inpatient regimens have shorter durations and more intense exercises and begin on the day of surgery or the first postoperative day.

Aggressive rehabilitation is believed to be important in preventing postoperative contracture of the soft tissue and in gaining better flexion postoperatively. Pua and Ong52 (n=1504) studied the significance of ambulation on the first postoperative day and found that it resulted in a significantly shorter LOS, lower hospitalization costs, and improved knee function. Zietek et al53 (n=66) increased the intensity of rehabilitation on the first postoperative day by adding an extra 15-minute walk with a walker 3 hours after an initial 15-minute walk. They found no detriment to the added intensity and suggested a further increase in intensity. However, when
In an immediate postoperative setting, the most important intervention in perioperative management of TKA is the protocol included preoperative patient education, ambulation on the day of surgery, spinal anesthesia, mobilization on the day of surgery, and preventing fibrous scar tissue formation in the joint, which tends to decrease knee motion.

The mechanism of CPM has been hypothesized to be twofold: facilitating the movement of synovial fluid to allow for better diffusion of nutrients into damaged cartilage with diffusion of other materials out, and preventing fibrous scar tissue formation in the joint, which tends to decrease ROM.

Studies on the use of CPM have had conflicting results. Early studies indicated that CPM had a short-term benefit after TKA by increasing knee ROM and improving wound healing. However, more recent studies seem to refute these findings, claiming no benefit in CPM after TKA. In an attempt to make sense of the conflicting evidence, several systematic reviews have been conducted. However, these reviews have had conflicting conclusions as well. Older reviews seem to favor the use of CPM, while more recent reviews seem to show no benefit. Conflicting conclusions of the systematic reviews were a result of different inclusion and exclusion criteria. Reviews that included studies in which post-TKA patients who received CPM were compared with patients whose knees were immobilized found a benefit with CPM. Contrastingly, reviews that only included studies in which patients who received CPM were compared with patients who received conventional physiotherapy found no benefit with CPM. This difference in comparison explains why earlier reviews found CPM to be beneficial—they were conducted at a time when the standard of care for acute postoperative TKA was knee immobilization. More recent reviews compared CPM with the current standard of care, physiotherapy, and found no difference. Thus, critical scrutiny of the literature against the backdrop of normal clinical practice provides a unified conclusion supporting postoperative rehabilitation in TKA, in the form of conventional physiotherapy or CPM, because knee motion is more beneficial than knee immobilization. Further, this unified conclusion supports the idea that CPM offers little to no additional benefit to conventional postoperative physiotherapy.

To validate the unifying theory concerning discordant conclusions in CPM studies and meta-analyses, forest plots were generated that stratified the control group to either postoperative immobilization or physical therapy. In the CPM vs immobilization data analysis, ROM was analyzed at time points of 3 and 12 months (Figure 3). The pooled data showed no significant ROM improvement at either time point. In the CPM vs physical therapy data analysis, the time points included discharge, 3 months, 6 months, and 12 months (Figure 4). Regardless of time point, none of the changes in ROM represented a clinically significant difference with the use of CPM when compared with the use of physical therapy.
in CPM vs immobilization at 12 months. This offers some insight into why CPM was thought to be beneficial when compared with immobilization but not when compared with physical therapy. Overall, the authors’ analysis of current literature suggests that there is little benefit to any patient receiving CPM after primary TKA in the backdrop of the current standard of care that includes postoperative physical therapy, indicating that CPM is an unnecessary overuse of medical resources.

**Long-term Postoperative Interventions**

**Outpatient Physical Therapy.** Physical therapy that begins after hospital discharge has long been considered the standard of care in the rehabilitation after TKA, reliably facilitating ROM, strength, and quality of life improvements. Outpatient rehabilitation can range from 3 to 8 weeks and can include multiple sessions per week. Ebert et al\(^6\) (n=108) noted that active knee flexion at the beginning of outpatient visits correlates strongly with knee flexion at 7 weeks after TKA, underscoring the importance of rehabilitation even after hospital discharge. Similarly, Brennan et al\(^6\) (n=321) recently reported that an increase in the number of days between hospital discharge and outpatient physical therapy was a significant factor in the prediction of disability and pain scores at the completion of rehabilitation, with an increase in the number of days correlating with an increase in pain and disability. In a survey of physiotherapists concerning best practices for rehabilitation, participants agreed that “aggressive physiotherapy should be met within 8 weeks, as the knee can become stiff as a result of tissue scarring down from lack of mobility.”\(^65\)

A key research issue, of recent importance due to the increased demands placed on rehabilitation services, has been the use of group physical therapy vs individual physical therapy. Naylor et al\(^6\) surveyed 93 TKA patients after their rehabilitation was complete and found no overall preference for either mode. The authors also confirmed the strengths of each mode: group-based therapy granted a psychosocial benefit, whereas the one-to-one therapy offered a more personalized approach. Aprile et al\(^6\) conducted a randomized, single-blind, crossover study (n=27) comparing individual and group rehabilitation. They found no significant differences in Short Form-36, WOMAC, and visual analog scale scores between patients at 1 month after TKA.\(^6\) Similarly, Ko et al\(^6\) conducted a randomized, superiority trial (n=249) comparing one-to-one therapy, group-based therapy, and a monitored home program. They found that “one-to-one therapy does not provide superior self-reported or performance-based outcomes compared with group-based therapy or a monitored home program, in the short term and the long term after total knee arthroplasty.”\(^6\) The outcome measures included the Oxford knee score, WOMAC score, and Short Form-12 score.

Outpatient physical therapy remains relevant in the clinical pathway follow-
ing primary TKA; however, current trends indicate a shift toward patient-specific regimens. Because evidence suggests both group therapy and individual therapy are viable options, patients can be assigned according to their individual preferences concerning physical therapy.

**Home Exercises and In-Home Telerehabilitation.** Both home exercise regimens delivered via a physician handout containing diagrammed exercises and telerehabilitation involving physical therapists interacting via live, 2-way video feeds have recently garnered attention as resource-saving rehabilitation modalities.

According to Dr Froimson, President of the Cleveland Clinic Health System, “The goals of a home-based clinical care path . . . include patient and family engagement, shared decision-making, and flexibility regarding changes in plans to accommodate changing needs.” He continued, “Patients discharged home consume significantly fewer resources and cost the system about one-third as much as those sent to an inpatient postacute facility.” In a recent RCT (n=34), Buler et al79 compared supervised physiotherapy with home exercises. They found no differences in visual analog scale score, ROM, WOMAC score, and Short Form-36 score between the groups and noted that home exercises were approximately $209 less expensive. Similarly, Rajan et al71 randomized patients (n=120) to receive either usual-care physiotherapy or a well-structured home exercise regimen. At 1-year follow-up, only a clinically insignificant difference of 2.9° in ROM was seen. Kramer et al72 randomized patients similarly (n=160) and found no significant differences in Knee Society score, WOMAC score, Short Form-36 score, 6-minute walking test, 30-second stair climbing time, and knee flexion ROM at 3 months and 1 year after TKA. Han et al73 confirmed these findings in a multicenter, noninferiority RCT (n=490). They reported no significant differences in pain, knee function, ROM, or 50-foot walk times at 6 weeks postoperatively. Home-based care, as per current evidence, is a viable and more efficient alternative to outpatient rehabilitation.

Telerehabilitation is a newer medium for postoperative rehabilitation; advances in technology and Internet availability have made wider use of these technologies possible. Russell et al84 conducted an RCT (n=65) evaluating the equivalence of an Internet-based telerehabilitation program with conventional outpatient physical therapy. The authors noted comparable ROM, muscle strength, limb girth, pain, timed up-and-go, quality of life, gait, and WOMAC scores. They also noted that the telerehabilitation intervention was well received by participants, who reported a high level of satisfaction with this novel technology. Similarly, a higher-powered RCT (n=205) that compared face-to-face home rehabilitation with telerehabilitation found the latter to be noninferior in terms of WOMAC score, knee injury and osteoarthritis outcome score, knee function, knee strength, and ROM. Examining cost concerns, Tousignant et al76 used an RCT (n=197) to compare telerehabilitation with home-visit rehabilitation. The authors found telerehabilitation to be less expensive via a total cost analysis—a differential of -$263 (95% confidence interval, -$382 to -$143) in Canadian dollars. However, in lieu of a net analysis, telerehabilitation was only significantly less expensive when the patient lived more than 30 km from the health care center. Telerehabilitation offers yet another way for health care professionals to account for patient-specific factors in prescribing postoperative physical therapy. For patients with the technological accessibility and savvy, a telerehabilitation regimen may be indicated.

**Adjunctive Interventions**

**Neuromuscular Electric Stimulation.** In an attempt to improve TKA outcomes, an array of adjunctive interventions is under investigation. Neuromuscular electric stimulation (NEMS) involves electrical stimulation of lower limb muscles using a transcutaneous electrical nerve stimulation system. Neuromuscular electric stimulation is hypothesized to improve muscle strength of the quadriceps and to train patients without sufficient volitional quadriceps activation by engaging neurophysiological mechanisms after TKA.77 Levine et al78 in an RCT (n=70), showed that NMES combined with unsupervised at-home exercises was noninferior to traditional supervised physiotherapy at 6 months postoperatively regarding flexion, extension, Knee Society score, WOMAC score, and timed up-and-go. In a small RCT (n=30), Avramidis et al79 applied NMES to the vastus medialis for 6 weeks postoperatively as an adjunct to conventional physical therapy. The authors found a significant increase in walking speed at 3 months, but the Hospital for Special Surgery knee score was unchanged. Similarly, Demircioglu et al80 (n=60) applied an adjunctive NMES protocol—5 days a week for 4 to 6 weeks—to a standard exercise protocol in an RCT. They found that NMES improved ROM and timed up-and-go at 1 month but not at 3 months postoperatively. They also measured better WOMAC scores at both 1 and 3 months. The authors concluded that NMES therapy added to a standard exercise protocol offers superior outcomes. Although few studies have examined the long-term effects of NMES, in a small RCT (n=35), Stevens-Lapsley et al81 noted that improvements in quadriceps strength, hamstring strength, stair climbing time, timed up-and-go, and 6-minute walking test persisted until 1 year after TKA. In a high-powered RCT (n=200), Petterson et al82 showed that strength, activation, and function were similar between the exercise and exercise—NMES groups at 3 and 12 months. However, both groups were stronger and exhibited better function than the standard-of-care group at both time points.

Overall, NMES is a relatively new modality in the postoperative course of primary TKA. Preliminary evidence suggests a slight improvement in clinical out-
comes with the use of NMES.

**Wii-Based Home Rehabilitation.** Balance training has been included in rehabilitation after TKA.\(^{63,64}\) Given the recent prevalence of Wii (Nintendo, Kyoto, Japan) console systems in homes and the inclusion of Wii Fit, the concept of Wii-based home rehabilitation via balance training has emerged as an adjunct to traditional physiotherapy. Wii Fit games encourage lower extremity movement, challenge balance, and require players to remain in a standing position during play—activities that have the potential to address rehabilitation goals involving recovery of lower extremity function.\(^{65}\) McPhail et al\(^{86}\) (n=18) conducted a preliminary trial in patients recovering from lower limb fractures. The Wii Fit regimen failed to show clinically meaningful differences in a range of measurements, including gait parameters, lower extremity functional scale, and step test.\(^{86}\) Similarly, in an RCT (n=50), Fung et al\(^{85}\) administered 15-minute sessions of Wii Fit after traditional physical therapy sessions. They found no significant differences between the groups regarding pain, knee flexion, knee extension, walking speed, timed standing tasks, lower extremity functional scale, activity-specific balance confidence scale, and patient satisfaction with therapy services.\(^{85}\)

**Clinical Relevance**

In the lengthy clinical pathway from scheduling a patient for TKA to the patient’s resuming normal activity, many options—old and new—exist in the interest of maximizing patient outcome. Overall, evidence seems to suggest that preoperative rehabilitation and education are unsuccessful at enhancing outcomes. Inpatient rehabilitation remains a mainstay before releasing a patient and is effective. Continuous passive motion has been heavily investigated without much consensus, but the current authors’ analysis along with recent evidence supports the conclusion that CPM offers little benefit to primary TKA patients in lieu of standard-of-care physical therapy. Outpatient rehabilitation is incredibly popular. However, given its cost, inconvenience, and increased load on limited health care resources, outpatient rehabilitation is being slowly replaced by unsupervised home exercises and telerehabilitation without any adverse effects. Adjunctive therapies such as NMES have begun to emerge, but their long-term advantage needs to be substantiated. New opportunities such as mobile application–based physical therapy hold promise in enhancing patient satisfaction and reducing health care resource utilization by granting increased autonomy, digitizing patient management, identifying outliers for more intensive therapy, and potentially enhancing outcomes. These new opportunities require further investigation and hold promise for a health care utilization scheme that can adequately manage the increasing demand for TKA services.

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