Short and Mid Term Outcome of Total Knee Arthroplasty. The Effect of Rehabilitation

23

Kyriakos Avramidis and Theofilos Karachalios

Introduction

Total knee arthroplasty (TKA) is the most common procedure performed for end stage osteoarthritis (OA) in older individuals. Current data from 21 European countries reveal that the annual incidence of TKA is 109 procedures per 100,000 persons, which is more than twice that reported in 1998 [1]. TKA reliably reduces pain and improves function in patients with knee OA and 90 % of patients report reduced pain, improved functional ability and greater health related quality of life after surgery [2]. Moreover, 85 % of patients who undergo TKA report being satisfied with the outcome [2]. Despite the well documented success of this procedure, patients continue to demonstrate physical impairment and functional limitations following TKA compared with individuals without knee disease [3]. One month after TKA quadriceps strength drops to 60 % of preoperative levels, even when traditional postoperative rehabilitation is initiated within 48 h after surgery [4, 5]. This quadriceps weakness persists years after surgery, based on comparisons with age-matched controls [6]. Similarly, functional performance is reported to worsen by 20–25 % 1 month after TKA [7] and reduced function persists with reports of 18 % slower walking speed and 51 % slower stair-climbing speed compared to age-matched controls at 12 months after TKA [3]. Despite these documented impairments and activity limitations, there is little evidence to support the introduction of structured rehabilitation to this population. In 2003, the National Institute of Health (NIH) 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 preoperative or postoperative rehabilitation intervention" [2]. Currently, there is no universally accepted rehabilitation protocol for patients after TKA and rehabilitation paradigms are often institution or surgeon specific [8, 9].

In 2007, the most recent meta-analysis on the effectiveness of physical therapy following TKA concluded that physical therapy has no long-term benefits [10]. However, these conclusions were based on only five studies that met the inclusion criteria for the meta-analysis. Potential reasons for the lack of demonstrated efficacy of these trials are the following: (a) none of the included

K. Avramidis, MD, DSc
Orthopaedic Department,
General Hospital of Larissa,
Larissa, Hellenic Republic

T. Karachalios, MD, DSc (✉)
Orthopaedic Department, Faculty of Medicine,
School of Health Sciences,
Center of Biomedical Sciences (CERETETH),
University of Thessalia,
University General Hospital of Larissa,
Mezourlo region, Larissa 41110, Hellenic Republic
e-mail: kar@med.uth.gr

T. Karachalios (ed.), *Total Knee Arthroplasty: Long Term Outcomes*,
DOI 10.1007/978-1-4471-6660-3_23

trials examined the use of a high intensity, long duration rehabilitation program initiated after discharge from hospital, (b) trials in which the intervention consisted of an electrical adjunct to physiotherapy such as the use of continuous passive motion (CPM) or neuromuscular electrical stimulation (NMES) were excluded.

The purpose of this review is to thoroughly evaluate randomized controlled trials (RCTs) and other quality studies in order to determine the effectiveness of structured and systematic postoperative rehabilitation on the short and long term functional recovery of patients after TKA.

Strengthening Interventions

Loss of quadriceps strength after TKA has been documented extensively [4–7]. However, recent studies suggest that hamstring muscle dysfunction [11] and hip abductor muscle weakness [12] are also present after the operation and should be addressed during rehabilitation. Rehabilitation programs which incorporate higher intensity, progressive resistive exercises that target all major muscle groups of the lower extremity have demonstrated superior mid-term [13] and long-term [14–16] strength and functional gains compared with lower intensity programs. Moffet et al. [13] has evaluated the effectiveness of an intensive functional rehabilitation (IFR) program on the functional ability and quality of life (QOL) of patients who underwent primary TKA. Two months after the operation, subjects were randomly assigned to either a group with IFR ($n=38$) who received 12 supervised rehabilitation sessions combined with home exercises between months 2 and 4 after TKA, or to a control group ($n=39$) who received standard care. The specific strengthening exercises, performed in a supine or seated position, consisted of maximal isometric pain free contractions (knee extensors and flexors) at different angles of knee flexion and dynamic (concentric-eccentric) contractions against gravity (hip abductors). All participants were evaluated at baseline (2 months after TKA), immediately after IFR (4 months after TKA) and 2 and 8 months later (6 and 12 months after TKA). The primary outcome measure was the 6 min walk test (6-MWT) at different time intervals, the WOMAC pain score, WOMAC difficulty score and SF-36 Health Survey. Patients in the IFR group walked significantly longer distances in 6 min and had less pain, stiffness and difficulty in performing daily activities compared to controls. Positive changes in QOL (PCS, MCS) in favor of the IFR group were also observed. The authors conclude that IFR was effective in improving short and mid-term functional ability after uncomplicated primary TKA, and suggest that in order to maintain these functional improvements in the long term (1 year post-surgery), more intensive rehabilitation should be introduced during the sub-acute recovery period (2–4 months after TKA). In a recent RCT, Petterson et al. [14] applied a progressive muscle strengthening protocol with or without the addition of NMES commencing 3–4 weeks after TKA and compared these two groups of patients (Exercise group and Exercise-NMES group, 100 patients each) to an embedded cohort of patients (control group) who received “standard rehabilitation” focused on functional training. The active treatment groups received two to three sessions of outpatient physical therapy per week for a total of 6 weeks. Treatment effects were evaluated by a burst superimposition test to assess quadriceps strength, knee range of motion (ROM), timed up and go test (TUG), stair climbing test (SCT) and 6 min walk (6-MW) measurements, SF-36 as well as completion of the knee outcome survey activities of daily living scale (KOS-ADLS) at 3 and 12 months postoperatively. There were no significant differences between the exercise and exercise-NMES groups on any outcome measure at 3 and 12 months ($P>0.08$); however, both groups significantly improved on all scales from baseline to 3 and 12 months ($P<0.001$ for all) compared to controls, with the exception of the mental component score (MCS) of the SF-36 which only improved from 0 to 3 months. In other words, strength, activation and function were similar between the exercise and exercise-NMES groups at 3 and 12 months. The standard care group was weaker and exhibited worse function at 12 months compared to both treatment groups. The authors therefore conclude that progressive lower limb muscle strengthening can enhance clinical improvement after TKA, achieving similar short and long term functional recovery approaching the functional level of healthy older adults. The above studies [13, 14] applied high intensity programs 2 and 1 month after surgery, when strength and functional deficits were already profound [3–5], based mainly on concerns related to the assumption that a higher intensity intervention initiated immediately following hospital discharge, could lead to increased pain and swelling and ultimately to poorer ROM and functional outcomes. Bade et al. [16] in another recent RCT, attempts to assess clinical outcomes of a long duration IFR program initiated immediately after discharge from hospital in eight TKA patients. Effects were compared to those of a control group of another eight patients who participated in a lower intensity rehabilitation program. At the 3.5 and 12 week (end of rehabilitation) time points, patients in the IFR group had better functional performance and greater quadriceps strength compared to the control group and this improvement was maintained at 52 weeks. The high intensity program did not impair knee ROM and did not result in any musculoskeletal injuries in this small group of patients. Evgeniadis et al. [17] reports that TKA patients discharged from an 8 week home supervised strengthening exercise program had significantly greater knee flexion and extension active ROM compared to a control group who received only inpatient rehabilitation (mean flexion 98.42 and 80.42° and mean extension −0.8° and −6.42° respectively) 14 weeks after surgery. This improvement of active ROM was accompanied by similar benefits in functional autonomy.

Whole body vibration (WBV) is an exercise mode which has been suggested in order to rehabilitate patients with lower extremity weaknesses and provide an alternative strengthening method in older patients who may not be able to perform standard exercise programs [18]. Johnson et al. [19] investigated the use of WBV as an alternative strengthening regimen in the rehabilitation of individuals after TKA, in comparison with traditional progressive resistance exercise (TPRE). Individuals, 3–6 weeks after TKA, received physical therapy with WBV or TPRE for 4 weeks. Knee extensor strength improved at a level of 84.3 % in the WBV and at a level of 77.3 % in the TPRE group. TUG scores improved at a level of 31 % in the WBV and at a level of 32 % in the TPRE group. There were no significant differences between groups for strength, muscle activation and mobility and no adverse effects were reported in either group. In this study both WBV and TPRE proved equally effective in improving strength and function during rehabilitation after TKA.

Continuous Passive Motion After TKA

The concept of continuous passive motion (CPM) was introduced into orthopaedics by Salter et al. in 1980 [20]. They studied the biologic effect of CPM on the healing of full thickness defects in rabbit knee articular cartilage and found it strikingly beneficial. Salter suggested that immobilization was detrimental to joints, motion was beneficial and CPM minimized forces across damaged joint surfaces. For motion to be continuous, it had to be applied passively, as muscles would fatigue with continuous active movement of a joint [20–22]. Encouraged by these studies, Coutts et al. [23] were the first to introduce continuous passive motion into the postoperative rehabilitation of patients undergoing TKA. They demonstrated improvement in the range of knee motion, reduction in the length of hospital stay and a dramatic decrease in the use of pain medication in a small group of patients receiving CPM for 20 h a day compared to controls who kept their knees immobilized for the first four postoperative days. After this study, the use of CPM devices after TKA increased dramatically and CPM has been widely used as an adjunct to physiotherapy after TKA for the past three decades. Despite this widespread use, however, studies on the effectiveness of CPM have not supported risk and benefit issues and its widespread use remains controversial. Earlier studies (before 2000) recommend its use [24–31], whereas more recent studies have found it to be less valuable in the rehabilitation of TKA [32–37]. Studies presented by Maloney [24], Johnson [25], McInnes [26] and Ververeli [27] have demonstrated a significant increase in the range of motion of the knee, at discharge, due to an increase in active flexion and a decrease in swelling. However, a longer term effect was not evident at 6 weeks, 3 months, 1 and 2 years after operation. At discharge, active knee extension was reported to be less and flexion contracture more in CPM treated knees [25, 27, 38]. This "extensor lag" was found to be transient and was attributed to flexor muscle stiffness and quadriceps muscle weakness of the knees subjected to CPM [38]. In all these studies which report faster knee recovery during the hospital stay, duration of CPM applications varied from 16 to 24 h per day and it was performed during the first 7 days after TKA. Moreover, knees in control groups were immobilized for 3–7 days in a splint, whereas the experimental groups received early postoperative CPM applications [23–29]. These results cannot be applied to contemporary practice because a long period of immobilization is no longer recommended and early movement is always promoted after TKA [35]. CPM is generally applied to patients after TKA during the postoperative hospitalization period (5–10 days) and current recommendations regarding the length of its application in order to attain treatment benefits are between 3 and 5 h in total per day [32]. However, in practice each session cannot last longer than 2 h because patients have to be allowed time for conventional physical therapy interventions, occupational therapy visits, nursing care and radiographic and medical assessments. Furthermore, they need time to achieve all of their rehabilitation goals, in addition to knee flexion, such as transferring and walking with aids, before being discharged [35]. Lenssen et al. [36] has investigated the effectiveness of prolonged CPM use at home for 17 consecutive days after surgery as an adjunct to standardized physiotherapy and found neither long term effects of this intervention nor transfer to better functional performance. Conflicting evidence exists with respect to the use of analgesics for postoperative pain control in TKA patients using CPM. Colwell and Morris [28] reported a statistically significant decrease in the use of narcotic analgesics in patients using a CPM device in a small RCT study, whereas Pope et al. [29] in a larger, more recent, RCT study comparing three groups of patients (no CPM, CPM of 0–40° and CPM of 0–70°) detected a significant increase of analgesic requirement in the two groups who had CPM. Pope's study also demonstrates significantly increased mean blood drainage postoperatively in the high flexion group who had CPM of 0–70° (1,558 ml) compared with the "no CPM" group (956 ml) and the 0–40° CPM group (1,017 ml).

There is controversy concerning the effect of CPM on the incidence of deep vein thrombosis (DVT) after TKA. Many authors have not found any difference in DVT with CPM applications [27, 32, 39], whereas others have found less DVT in CPM application groups, although this finding may be attributed to the fact that control knees were immobilized [30, 40]. Coutts et al. [30] has presented a multi-center study, in 1983, comparing manipulation rates after TKA in a CPM group (137) and a control group (129) of patients. They reported no manipulations in the active treatment group, while 21 % of the knees in the control group required manipulation. Subsequent studies [27, 31, 41] also support the use of continuous passive motion in order to decrease the rate of manipulation (and its costs) for poor range of motion after TKA. The effects of CPM on the healing process after TKA remain controversial. Wound swelling has been reported to be decreased with the use of CPM after TKA [30, 38]. A wound complication is defined as an infection or other condition that necessitates a change in the postoperative regimen. According to this definition Maloney et al. [24] have reported an increased incidence of wound complications in a series of CPM application after TKA, mainly haematomas, superficial and deep wound infections. Davis [42] report increased aseptic wound drainage with the use of CPM. Conflicting reports by Bennett [43] and Colwell and Morris [28] show no significant difference in wound drainage. Johnson et al., in his landmark paper [25], measured the transcutaneous oxygen tension of knee wounds and found decreased viability of the edges of the wound (particularly the lateral edge) with knee flexion beyond 40° during the first three post-operative days. On the basis of these results, a protocol was designed for CPM to minimize the detrimental effects on wound viability. This protocol included restricting flexion of the knee from 0 to 40° for the first three postoperative days and then slowly increasing the range of motion by daily increments to reach 90° on the sixth day. The CPM machine was removed on the seventh day. In Johnson et al.'s study 102 patients undergoing TKA were randomly assigned to an immediate CPM group which followed the above protocol and a control group which had their knees immobilized in a splint for 7 days. There was no difference in the incidence of infection or wound healing between the two groups, demonstrating that if CPM is not aggressive, the incidence of problems with wound healing will not increase. Speed of CPM made little difference in terms of wound viability, although a setting of one cycle per minute maximized oxygenation without the discomfort associated with faster settings.

Aquatic Therapy

In Europe aquatic therapy, such as pool exercise, is commonly used in the aftercare of patients following TKA. Proponents of water based rehabilitation protocols argue that exercising in warm water may reduce stress on the joint and allow an individual to strengthen their lower extremity using water as resistance, while taking advantage of the weight reducing effects of buoyancy [44]. This weight reduction, in line with to Archimedes law, protects the joints and permits better movement, muscular reinforcement through proprioceptive mechanisms and accelerated mobilization of the operated limb [45]. Resistance to movement can be varied by changing the speed of motion and by increasing water turbulence. Because pool exercises require a continuous balance response, muscular coordination is improved. Patients overall report a sense of pleasure and pain relief while exercising in water [44, 45]. Liebs et al. [44] has found that water based therapy can be safely started as early as 6 days after TKA, provided the wound is covered with a waterproof adhesive dressing (Op-Site). These authors have also shown that patients randomized to start water based therapy on the sixth postoperative day had better WOMAC, SF-36, and Lequense Knee scores 12 and 24 months after TKA, compared to patients who were randomized to start the same program on the 14th postoperative day. While these results were not statistically different between groups, the effect of the size of the intervention on WOMAC score was similar to the effect of nonsteroidal anti-inflammatory drugs on functional limitations associated with knee OA. The change in WOMAC score also exceeded the minimal clinically important difference cut-off of 24 months following surgery. The authors conclude that early aquatic therapy after TKA led to a clinically important improvement in patient outcomes when compared with late aquatic therapy. However, these authors used only self-reported measures of function and did not compare the outcomes of aquatic based therapy to other land-based rehabilitation programs. Valtonen et al. [46] analyzed the effect of a 12 week progressive aquatic resistance training program on mobility limitations (walking speed and stair ascending time), self-reported function (WOMAC), knee extensor and flexor power assessed isokinetically and quadriceps muscle cross sectional area (CSA) assessed by computed tomography. Fifty patients in the late stages of recovery after TKA (average 10 months postoperatively), were randomized to either an aquatic program group (26) in which progressive strengthening exercises were performed in the pool, or to a control group of patients (24) advised to maintain their usual physical activity level. At the end of the 12 week training program, subjects in the active treatment group had better knee flexion and extension power (48 % and 32 % respectively), greater thigh muscle CSA (3 %), faster habitual walking speed (9 %) and faster stair ascending time (15 %) compared to controls. No differences were found for WOMAC scores between groups.

The authors also evaluated the maintenance of observed aquatic training induced benefits at a follow up of 12 months after the end of the intervention [47]. At this 1 year observation period, knee extensor and flexor powers were still significantly higher (32 % and 50 % respectively) in the active treatment group compared to the control group, while all the significant 12 week improvements in muscle CSA, walking speed and stair ascending time had been lost. The authors suggest that aquatic resistance training should be continued to maintain the training induced benefits on mobility. Harmer et al. [48] randomized 102 patients scheduled for TKA to receive either land based (49) or water based (53) physical therapy, commencing 2 weeks after surgery. Both groups attended 1 h sessions twice a week for 6 weeks. The same therapist supervised both water and land based treatment and the exercise prescription was highly standardized to ensure that the only difference between treatment groups was the medium (water versus land). Patients were evaluated 8 and 26 weeks after TKA and there were no differences between groups for WOMAC score, knee ROM, 6 min walk test and stair climbing power (SCP), although both groups demonstrated significant improvement compared to baseline. The authors conclude that water-based therapy was not particularly advantageous with respect to functional outcome or clinical metrics, although it may be a valid alternative treatment for rehabilitation after TKA.

Balance Training

Impairment of balance is a serious problem in fully recovered TKA patients [49] along with persistent muscle weakness [3, 6]. After TKA patients are at a higher risk of falling and sustaining further orthopaedic injury [50, 51]. During a 6 month observational period of a cohort of patients 6–12 months following their TKA, Matsumoto et al. [50] identified a 32.9 % incidence of fall. Swinkels et al. [51] reported a recent preoperative history of falling to be common (24.2 %) in people undergoing TKA and approximately 45 % of these patients fell again in the year following surgery. Therefore, resolving balance impairments after TKA, should be an important goal of physical therapy. Two studies with similar methodology have assessed the effectiveness of adding specific balance exercises (agility and perturbation techniques) to a functional training (FT) protocol. Piva et al. [52] has compared the effects of balance training (B) and function training (FT) on mobility outcome in small sample groups. The interventions were 6 weeks of supervised FT or FT + B program, followed by a 4 month home exercise program. Outcome data were collected at baseline, after completion of the supervised program (2 months) and at completion of the 4 month home exercise period (6 months after randomization). Both groups demonstrated clinically important improvements in lower extremity functional status. Differences between groups did not have adequate power to demonstrate statistical significance; however, the degree of improvement seemed higher for gait speed, single leg stance time and stiffness in the FT + B group compared with the FT group. Liao et al. [53] has found that the addition of 8 weeks of balance exercises to a postoperative rehabilitation program significantly improved (at the end of the intervention) functional forward reach, single leg stance, sit to stand test, stair climbing time, 10 min walk time, timed up and go scores and the WOMAC Index scores to a greater extent than a control group which did not receive balance retraining exercises (all $P < 0.001$). It should be noted that Liao et al. had a larger sample size (130 versus 43 patients) and longer intervention (8 versus 6 weeks) than the study by Piva et al. Additionally, patients randomized to receive balance retraining in Liao's study also had longer session duration than subjects of the control group in the same study (up to 90 min versus 60 min). The authors conclude that 8 weeks of additional balance training can improve functional performance in mobility after TKA. Fung et al. [54] tested the use of an integrated Wii Fit™ commercially available motion controlled video game system [55] in the rehabilitation of outpatients following TKA. In addition to standard therapy, subjects randomized to the active treatment group (27) received 15 min of Wii Fit™ gaming activity, while the control group (23) received 15 min of additional lower extremity exercise. There were no differences between groups for active knee flexion and extension, distance covered in the 2 min walk test, numeric pain rating scale, activity specific balance confidence scale, lower extremity functional scale or length of outpatient rehabilitation. These findings suggest that the addition of Wii Fit™ as an alternative to lower extremity strengthening may be an appropriate rehabilitation tool.

Neuromuscular Electrical Stimulation (NMES)

One month after TKA impairment in quadriceps muscle strength is predominantly due to central activation deficits (also referred to as "reflex inhibition"), but is also influenced to a lesser degree by muscle atrophy [4, 5, 56]. Although the neurophysiologic mechanisms for quadriceps muscle voluntary activation deficits are not fully understood, spinal reflex activity from pain or effusion in the knee joint may alter afferent input from the injured joint and result in diminished efferent motor drive to the quadriceps muscle that reduces muscle strength [57]. Early studies by Gibson [58] and Martin [59] demonstrated that neuromuscular electrical stimulation (NMES) can prevent muscle atrophy in patients with knee OA who are awaiting or recovering from TKA. Recent studies by Thomas [60] and Stevens [61] have demonstrated the potential of NMES to mitigate voluntary activation deficits and prevent muscle atrophy early after surgery, thus restoring normal quadriceps muscle function more effectively than voluntary exercise alone. How NMES improves muscle strength is unclear, though some theories have emerged. Firstly, the intensity of the muscle contraction produced during stimulation may be greater than that without NMES (at least 30–50 % of maximal voluntary effort), thus overloading the muscle sufficiently to induce strength gains [60]. Secondly, NMES may alter motor recruitment inducing activation of a greater proportion of type II muscle fibers which are larger than type I, so greater activation of type II fibers maximizes force production [62]. Results of studies applying NMES to the quadriceps muscle of patients after TKA are promising. Gotlin et al. [63] randomized 40 patients who underwent TKA to either a control group (19) or an NMES group (21). Both groups received conventional physical therapy including CPM to the affected limb, ambulation training, ROM exercises and activities of daily living (ADL) training. Within the first postoperative week, the active treatment group additionally received, twice daily for 1 h during CPM treatment, electrical stimulation (frequency of 35 Hz, stimulation time 15 s followed by a 10 s rest interval) with electrodes placed over the proximal femoral nerve and the distal vastus medialis obliquus (VMO) muscle. Active treatment group patients reduced their extensor lag from 7.5 to 5.7°, whereas control group extensor lag increased from 5.3 to 8.3° in the same time frame. These trends were significantly different ($p < 0.01$). In addition, NMES patients had a significantly different ($p < 0.05$) length of hospital stay (7.4–6.7 days). As the greatest loss of quadriceps strength occurs in the first month following TKA [4, 5], Avramidis et al. [64] examined the use of NMES on the quadriceps muscle of the operated limb for the first six postoperative weeks in addition to standard physical therapy and demonstrated a statistically significant improvement in patients' walking speed at 6 weeks ($p = 0.0002$) as well as a "carry over" effect 6 weeks after discontinuation of treatment (12 weeks after the operation, $p < 0.0001$). Based on this original study, the same author also attempted to investigate the long term effect of this intervention 1 year after TKA, at which time most of the patients' functional improvement was expected to have occurred [65]. Seventy patients who underwent TKA were randomly assigned to either an NMES group (35) receiving electrical stimulation of the vastus medialis muscle in addition to a traditional physical therapy program or a control group (35) who followed only the same physical therapy protocol, for 6 weeks. NMES was initiated on postoperative day 2 and was applied twice a day for 2 h on each occasion

(4 h total daily treatment) while the patient was lying in bed or sitting. The neuromuscular stimulator was set to 40 Hz, a pulse duration of 300 μs and an 8 s on time followed by an 8 s rest time with the current intensity set at the patient's maximum tolerance. Compared with the control group the NMES group demonstrated faster walking speeds and better scores on the Oxford Knee Score and American Knee Society function score at 6 and 12 weeks following TKA; however, differences between groups were no longer significant at 52 weeks. The NMES group also had significantly better SF-36 physical component (PCS) scores at 6, 12 and 52 weeks postoperatively compared to the control group. These gains were secondary to an initial faster recovery of quadriceps muscle strength and subsequent ability to participate more fully in the voluntary exercise program. No complications were associated with the use of NMES beginning on postoperative day 2, although 3 of the 38 originally recruited patients in the NMES group abandoned use of the stimulator due to discomfort, thus leaving the group with 35 patients who attended subsequent follow up evaluations. In a similar study, Stevens-Lapsley et al. [66, 67] examined the use of NMES to the quadriceps muscle early after TKA utilizing a randomized, unblinded study design. Sixty-six patients undergoing TKA were randomly assigned to receive either standard rehabilitation (control group) or standard rehabilitation plus NMES applied to the quadriceps muscle. Electrical stimulation treatment began on postoperative day 2, continued for 6 weeks and was applied twice per day for 15 isometric contractions on each occasion (a total of only 30 min per day). The stimulator was set to deliver a biphasic current, using a symmetrical waveform, at 50 Hz and a pulse duration of 250 μs, for a 15 s on phase followed by a 45 s rest time with the current intensity set at the patient's maximum tolerance. Data for muscle strength, functional performance and self-report measures (WOMAC Index) were obtained before surgery and at 3.5, 6.5, 13, 26, and 52 postoperative weeks. Compared with the control group, the NMES group demonstrated superior quadriceps strength, hamstring strength, 6 min walking distances, TUG times, SCT times, and active knee extension at 3.5 weeks after TKA. No differences between groups were noted for changes in the SF-36 (MCS and PCS) and WOMAC scores. At 52 weeks, differences between groups were attenuated but remained significant (favoring NMES) for quadriceps and hamstring muscle strength, TUG, SCT, 6MWT, SF-36 MCS and WOMAC scores. Improvement in active extension ROM tended to be better in the NMES group ($p = 0.08$). Similarly to the previous study, no adverse events were observed with the utilization of NMES beginning on postoperative day 2. A key observation from the Stevens-Lapsley et al. [66, 67] trial was that patients who were capable of achieving higher stimulation training intensities had greater quadriceps muscle strength and activation gains compared with those utilizing lower intensities. Therefore, increasing the comfort of NMES to accomplish this goal seems to play a role. Electrode size is important because it has a direct effect on current density, with smaller electrodes resulting in higher current density and potentially uncomfortable stimulation before reaching maximum muscle contraction torque. In both Avramidis's and Stevens-Lapsley's studies electrodes were applied to the skin over the vastus medialis muscle and lateral side of the thigh and connected to the "active" and "indifferent" leads respectively. Avramidis et al. [65] utilized 70 × 70 mm electrodes (Pals Plus, Nidd Valley Med., Knaresborough, UK), a shorter rest time (8 s), and longer NMES treatment duration of 2 h per session, whereas Stevens-Lapsley et al. [66, 67] utilized larger 76 × 127 mm electrodes (Supertrodes, SME Inc., Wilmington, USA), as well as longer rest-times (45 s) and shorter NMES treatment times of 15 min per session. These differences may have enabled patients to achieve higher stimulation intensities and, thus, greater strength gains, which may explain why the trial by Stevens-Lapsley et al. [66, 67] observed long term benefits in addition to short term benefits. Though the results of several investigations indicate NMES may be beneficial following TKA, Petterson's recent randomized clinical trial [14] comparing (a) Exercise and (b) Exercise + NMES suggests that NMES (ten contractions, twice per

week for 6 weeks) initiated 1 month postoperatively, may not be any more beneficial than exercise alone. Specifically, the authors noted no differences between the exercise and exercise + NMES groups in quadriceps strength, activation or function at 3 and 12 months after TKA. Both groups, however, had better strength, activation and function 12 months postoperatively compared to a cohort receiving less intensive rehabilitation in the community. These results suggest that the timing and frequency of NMES treatment may be critical to patient outcomes. In this study, had the use of NMES commenced immediately after surgery it may have proved more effective, because preventing the early (within the first month) decline of muscle function is likely to be more effective than working to reverse losses after they occur. It is also possible that the frequency of NMES application (two times per week) may not have been sufficient to induce changes in quadriceps muscle strength and activation. In conclusion, early use of NMES (within the first month after TKA) and NMES delivered more than twice per week may be necessary.

Out-Patient Clinic and Home Based Therapy

Physical therapy conducted in an outpatient clinic allows the therapist to directly monitor patient progress and adjust the intervention to the patients' functional status. However, it is more expensive than home based rehabilitation programs and requires that the patient travel to the clinic, which may be difficult for an elderly population. Rajan et al. [68] randomized 120 patients and found no statistically significant benefit of outpatient physiotherapy in knee ROM at 3, 6 months and 1 year after TKA. Mockford et al. [69] randomized 150 patients into a group which received outpatient physiotherapy for 6 weeks and another group receiving no outpatient physiotherapy. No differences between groups were found for flexion and extension ROM, Oxford Knee Score (OKS), Bartlett patellar score (BPS) or SF-12 general health questionnaire 1 year after surgery. The conclusions drawn by Rajan et al. that there is "no need for outpatient physiotherapy after TKA" and by Mockford et al. that "a standard routine course of outpatient physiotherapy does not offer any benefit in the long term to patients undergoing TKA" are not supported by the methodologies and results from these studies. Unfortunately, however, in neither study was there standardization or a description of the protocol or duration of the outpatient physical therapy intervention, and only ROM and self-reported outcomes were assessed to make determinations about the effectiveness of outpatient rehabilitation. Additionally, 1 year after surgery patients in both studies had knee flexion range of motion (97° and 108°) which was lower than the cut off for functional range of motion (110°) and less than the 120° reported by Petterson et al. [14], suggesting that these patients were under-rehabilitated. In order to determine the effectiveness of home based therapy monitored via periodic telephone calls from a physical therapist, Kramer et al. [70] randomized 160 patients to receive either clinic based or home based therapy. Both groups were given two booklets of ROM and strengthening exercises with the prescription to perform them at home three times daily until their 12 week follow up, at which time they were advised to continue the home exercises at least once daily, indefinitely. A physical therapist familiar with the protocol evaluated the home based group weekly in order to monitor adherence and compliance with the protocol. The clinic based group attended outpatient therapy between weeks 2 and 12 after surgery, for two sessions per week of 1 h duration each and patients completed the common home exercises only twice on days that they attended clinic sessions. At the 12th and 52nd week follow-up, values for WOMAC, SF-36, 6 m walking, 30 s stair test, knee flexion ROM, and Knee Society clinical rating scale were significantly better compared to baseline in both groups and there was no relative advantage of one group over the other. Madsen et al. [71] compared late clinic based and home based rehabilitation, commencing 4–8 weeks after TKA. They allocated 80 patients undergoing the operation to either group based rehabilitation

(40) or individual, supervised home training (40). The group based rehabilitation consisted of 12 outpatient visits over 6 weeks, including strength-endurance exercises, education and self-management combined with home exercises. The control group performed home exercises, received an initial visit of a physical therapist in which the training program was adjusted to each individual's needs and one or two additional visits during the treatment period to further adjust the program. Three and 6 months after TKA, there were no differences between groups, after adjusting for baseline values, for self-reported measures (Oxford Knee Score, the physical function part of the SF-36, EuroQol-5 Dimensions), impairment metrics (leg extensor power, pain level during the power test) and performance metrics (tandem test for balance, 10 m walking test, 30-s and five times sit to stand tests). The authors conclude that individual, supervised home training and group based rehabilitation programs improved patients' quality of life and physical function equally 6 months after TKA.

Russell et al. [72] has evaluated the equivalence of an internet based tele rehabilitation program compared with conventional outpatient physical therapy for patients following TKA in Australia. Access to rehabilitation may be difficult for patients who live in rural or remote areas and one possible solution is the use of tele rehabilitation technology to enable delivery of such service from a distance. In this study 65 patients were randomized to receive a 6 week program of outpatient physical therapy either in the conventional manner or by means of an Internet based tele rehabilitation program. The primary outcome measure was the WOMAC score and secondary outcomes included the Patient Specific Functional Scale, TUG test, pain intensity, knee flexion and extension, quadriceps muscle strength, limb girth measurements and an assessment of gait. After the 6 week intervention, participants of both groups had significant improvement on all outcome measures ($p < 0.01$ for all); however, differences between groups were not significant for most of the above outcomes with the exception of the Patient Specific Functional Scale and the stiffness subscale of the WOMAC for which results were better in the tele rehabilitation group ($p = 0.04$). Despite the lack of between group differences, both groups were under rehabilitated; patients had residual knee flexion contractures and quadriceps lag on active knee extension, indicating significant residual weakness. Moreover, TUG times in both groups were still greater than 12 s at the end of the study, nearly 45 % longer than the TUG times reported by Petterson et al. [14] 3 months after TKA and 30 % longer than the TUG times in the active treatment group reported by Stevens-Lapsley et al. [66, 67] 6.5 weeks after TKA. These results suggest that ROM, strength and functional impairment are not completely resolved with this type of postoperative treatment strategy. The authors also acknowledge a number of limitations in their study, such as an inability to estimate patient compliance with the tele rehabilitation intervention at home and the lack of long term outcomes (only 6 weeks follow-up). Future research is needed to better assess long term effects, as well as the fiscal impact of this alternative mode of remotely delivered physical therapy.

Kauppila et al. [73] has tested whether a 10 day multidisciplinary rehabilitation program was effective in achieving faster and greater functional recovery after TKA. Patients in the active treatment group (44) attended the multidisciplinary program 2–4 months after the surgery. This program involved completing group exercise sessions with a physical therapist and attending lectures from a variety of health care personnel (orthopaedic surgeon, psychologist, social worker and nutritionist). The control group (42) followed usual care. The main measures assessed preoperatively and at 2, 6 and 12 month follow up were the WOMAC index, 15 m walk test, stair test and isometric strength measurement of the knee. The use of rehabilitation services were recorded with a use of a questionnaire. The active treatment group did not achieve functional recovery any faster and neither did their quality of life improve more than conventional care controls. Furthermore, the intervention did not reduce the use of postoperative rehabilitation services. However, patients who undergo TKA often have co morbidities including depression, obesity and cardiovascular impairments and such patients may benefit from a multidisciplinary rehabilitation treatment after surgery. Future studies are needed to test this hypothesis.

Conclusions

Physical therapy and rehabilitation protocols are critical to recovery after TKA. There is a large decrease in quadriceps muscle strength immediately after TKA, which is attributed to activation deficits and atrophy [4, 7]. Progressive strengthening exercise interventions of high intensity and early application of NMES should be used in order to attenuate early quadriceps weakness and the associated impairment. Further work is needed to fully elucidate the relationship between postoperative exercise protocols and outcomes, given that most studies do not accurately describe the "usual care" groups that were included as treatment arms in these randomized trials. Overall, the long term effect of structured physical therapy on the TKA outcomes is unclear.

References

1. Health at a glance 2011: OECD indicators. Paris: OECD Publishing; 2011.
2. NIH Consensus Statement on total knee replacement December 8–10, 2003. J Bone Joint Surg Am. 2004; 86A:1328–35.
3. Walsh M, Woodhouse LJ, Thomas SG, Finch E. Physical impairments and functional limitations: a comparison of individuals 1 year after total knee arthroplasty with control subjects. Phys Ther. 1998;78:248–58.
4. Stevens JE, Mizner RL, Snyder-Mackler L. Quadriceps strength and volitional activation before and after total knee arthroplasty for osteoarthritis. J Orthop Res. 2003;21:775–9.
5. Mizner RL, Petterson SC, Stevens JE, Vandenborne K, Snyder-Mackler L. Early quadriceps strength loss after total knee arthroplasty: the contributions of muscle atrophy and failure of voluntary muscle activation. J Bone Joint Surg Am. 2005;87A:1047–53.
6. Huang CH, Cheng CK, Lee YT, Lee KS. Muscle strength after successful total knee replacement. A 6 to 13 year follow up. Clin Orthop. 1996;328:147–54.
7. Mizner RL, Petterson SC, Snyder-Mackler L. Quadriceps strength and the time course of functional recovery after total knee arthroplasty. J Orthop Sports Phys Ther. 2005;35:424–36.
8. Cameron H, Brotzman S. The arthritic lower extremity: total knee arthroplasty. In: Brotzman SB, Wilk KE, editors. Clinical orthopaedic rehabilitation. 2nd ed. Philadelphia: Mosby; 2003. p. 465–74.
9. Ranawat CS, Ranawat AS, Mehta A. Total knee arthroplasty rehabilitation protocol. What makes the difference? J Arthroplasty. 2003;18:27–30.
10. Minns Lowe CJ, Barker KL, Dewey M, Sackley CM. Effectiveness of physiotherapy exercise after knee arthroplasty for osteoarthritis: systematic review and meta-analysis of randomised controlled trials. Br Med J. 2007;335:812. http//dx.doi.org/10.1136/bmj.39311.460093.BE.
11. Stevens-Lapsley JE, Balter JE, Kohrt WM, Eckhoff DG. Quadriceps and hamstrings muscle dysfunction after total knee arthroplasty. Clin Orthop. 2010;468:2460–8.
12. Piva SR, Teixeira PEP, Almeida GJM, Gil AB, DiGioia AM, Levison TJ, Fitzgerald GK. Contribution of hip abductor strength to physical function in patients with total knee arthroplasty. Phys Ther. 2011;91:225–33.
13. Moffet H, Collet JP, Shapiro SH, Paradis G, Marquis F, Roy L. Effectiveness of intensive rehabilitation on functional ability and quality of life after first total knee arthroplasty. A single-blind randomized controlled trial. Arch Phys Med Rehabil. 2004;85:546–56.
14. Petterson SC, Mizner RL, Stevens JE, Raisis L, Bodenstab A, Newcomb W, Snyder-Mackler L. Improved function from progressive strengthening interventions after total knee arthroplasty. A randomized clinical trial with an imbedded prospective cohort. Arthritis Rheum. 2009;61:174–83.
15. Bade MJ, Stevens-Lapsley JE. Restoration of physical function in patients following total knee arthroplasty. An update on rehabilitation practices. Curr Opin Rheumatol. 2012;24:208–14.
16. Bade MJ, Stevens-Lapsley JE. Early high-intensity rehabilitation following total knee arthroplasty improves outcomes. J Orthop Sports Phys Ther. 2011;41:932–41.
17. Evgeniadis G, Beneka A, Malliou P, Mavromoustakos S, Godolias G. Effects of pre- or postoperative therapeutic exercise on the quality of life, before and after total knee arthroplasty for osteoarthritis. J Back Musculoskelet Rehabil. 2008;21:161–9.
18. Roelants M, Delecluse C, Verschueren SM. Whole-body vibration training increases knee-extension strength and speed of movement in older women. J Am Geriatr Soc. 2004;52:901–8.
19. Johnson AW, Myrer JW, Hunter I, Feland JB, Hopkins JT, Draper DO, Eggett D. Whole-body vibration strengthening compared to traditional strengthening during physical therapy in individuals with total knee arthroplasty. Physiother Theory Pract. 2010;26:215–25.
20. Salter RB, Simmonds DF, Malcolm BW, Rumble EJ, MacMichael D, Clements ND. The biological effect of continuous passive motion on the healing of full-thickness defects in articular cartilage. An experimental investigation in the rabbit. J Bone Joint Surg Am. 1980;62A:1232–51.
21. Salter RB. Motion versus rest: why immobilize joints? J Bone Joint Surg (Br). 1982;64B:251.

22. Salter RB. The physiologic basis of continuous passive motion for articular cartilage healing and regeneration. Hand Clin. 1994;10:211–9.
23. Coutts RD, Kaita J, Barr R, Mason R, Dube R, Amiel D, Woo SLY, Nickel V. The role of continuous passive motion in the postoperative rehabilitation of the total knee patient. Orthop Trans. 1982;6:277–8.
24. Maloney WJ, Schurman DJ, Hangen D. The influence of continuous passive motion on outcome in total knee arthroplasty. Clin Orthop. 1990;256:162–8.
25. Johnson DP. The effect of continuous passive motion on wound healing and joint mobility after knee arthroplasty. J Bone Joint Surg Am. 1990;72A:421–6.
26. McInnes J, Larson MG, Daltroy LH. A controlled evaluation of continuous passive motion in patients undergoing total knee arthroplasty. JAMA. 1992;268:1423–8.
27. Ververeli PA, Sutton DC, Hearn SL. Continuous passive motion after total knee arthroplasty-analysis of costs and benefits. Clin Orthop. 1995;321:208–15.
28. Colwell CW, Morris BA. The influence of continuous passive motion on the results of total knee arthroplasty. Clin Orthop. 1992;276:225–8.
29. Pope RO, Corcoran S, McCaul K, Howie DW. Continuous passive motion after primary total knee arthroplasty. Does it offer any benefits? J Bone Joint Surg (Br). 1997;79B:914–7.
30. Coutts RD, Borden LS, Bryan RS, et al. The effect of continuous passive motion on total knee rehabilitation. Orthop Trans. 1983;7:535–6.
31. Kumar PJ, McPherson EJ, Dorr LD, Wan Z, Baldwin K. Rehabilitation after total knee arthroplasty: a comparison of 2 rehabilitation techniques. Clin Orthop. 1996;331:93–101.
32. Beaupre LA, Davies DM, Jones CA. Exercise combined with continuous passive motion or slider board therapy compared with exercise only. A randomized controlled trial of patients following total knee arthroplasty. Phys Ther. 2001;81:1029–37.
33. Davies DM, Johnston DWC, Beaupre LA, Lier DA. Effect of adjunctive range-of-motion therapy after primary total knee arthroplasty on the use of health services after hospital discharge. Can J Surg. 2003;46:30–6.
34. Leach W, Reid J, Murphy F. Continuous passive motion following total knee replacement: a prospective randomized trial with follow-up to 1 year. Knee Surg Sports Traumatol Arthrosc. 2006;14:922–6.
35. Denis M, Moffet H, Caron F, Quellet D, Paquet J, Nolet L. Effectiveness of continuous passive motion and conventional physical therapy after total knee arthroplasty: a randomized clinical trial. Phys Ther. 2006;86:174–85.
36. Lenssen TAF, Van Steyn MJA, Crijns YHF, Waltjé EMH, Roox GM, Geesink RJT, Van den Brandt PA, De Bie RA. Effectiveness of prolonged use of continuous passive motion (CPM) as an adjunct to physiotherapy, after total knee arthroplasty. BMC Musculoskelet Disord. 2008; 9: doi:10.1186/1471-2474-9-60.
37. Maniar RN, Baviskar JV, Singhi T, Rathi SS. To use or not to use continuous passive motion post-total knee arthroplasty. Presenting functional assessment results in early recovery. J Arthroplasty. 2012;27:193–201.
38. Ritter MA, Gandolf VS, Holston KS. Continuous passive motion versus physical therapy in total knee arthroplasty. Clin Orthop. 1989;244:239–43.
39. Lynch AF, Bourne RB, Rorabeck CH, et al. Deep-vein thrombosis and continuous passive motion after total knee arthroplasty. J Bone Joint Surg Am. 1988;70A:11–4.
40. Vince KG, Kelly MA, Beck J, Insall JN. Continuous passive motion after total knee arthroplasty. J Arthroplasty. 1987;2:281–4.
41. Lachiewicz PF. The role of continuous passive motion after total knee arthroplasty. Clin Orthop. 2000;380:144–50.
42. Davis D. Continuous passive motion for total knee arthroplasty. Phys Ther. 1984;64:709.
43. Bennett LA, Brearley SC, Hart JAL, Bailey MJ. A comparison of 2 continuous passive motion protocols after total knee arthroplasty. A controlled and randomised study. J Arthroplasty. 2005;20:225–33.
44. Liebs TR, Herzberg W, Rüther W, Haasters J, Russlies M, Hassenpflug J. Multicenter randomized controlled trial comparing early versus late aquatic therapy after total hip or knee arthroplasty. Arch Phys Med Rehabil. 2012;93:192–9.
45. Giaquinto S, Ciotola E, Dall'Armi V, Margutti F. Hydrotherapy after total knee arthroplasty. A follow-up study. Arch Gerontol Geriatr. 2010;51:59–63.
46. Valtonen A, Pöyhönen T, Sipilä S, Heinonen A. Effects of aquatic resistance training on mobility limitation and lower-limb impairments after knee replacement. Arch Phys Med Rehabil. 2010;91:833–9.
47. Valtonen A, Pöyhönen T, Sipilä S, Heinonen A. Maintenance of aquatic training-induced benefits on mobility and lower-extremity muscles among persons with unilateral knee replacement. Arch Phys Med Rehabil. 2011;92:1944–50.
48. Harmer AR, Naylor JM, Crosbie J, Russell T. Land-based versus water-based rehabilitation following total knee replacement: a randomized, single-blind trial. Arthritis Rheum. 2009;61:184–91.
49. Gage WH, Frank JS, Prentice SD, Stevenson P. Postural responses following a rotational support surface perturbation, following knee joint replacement: frontal plane rotations. Gait Posture. 2008;27:286–93.
50. Matsumoto H, Okuno M, Nakamura T, Yamamoto K, Hagino H. Fall incidence and risk factors in patients after total knee arthroplasty. Arch Orthop Trauma Surg. 2012;132:555–63.
51. Swinkels A, Newman JH, Allain TJ. A prospective observational study of falling before and after knee replacement surgery. Age Ageing. 2009;38:175–81.
52. Piva SR, Gil AB, Almeida GJM, DiGioia AM, Levison TJ, Fitzgerald GK. A balance exercise program appears to improve function for patients with total knee arthroplasty: a randomized clinical trial. Phys Ther. 2010;90:880–94.

53. Liao CD, Liou TH, Huang YY, Huang YC. Effects of balance training on functional outcome after total knee replacement in patients with knee osteoarthritis: a randomized controlled trial. Clin Rehabil. 2013;27:697–709.
54. Fung V, Ho A, Shaffer J, Chung E, Gomez M. Use of Nintendo Wii Fit™ in the rehabilitation of outpatients following total knee replacement: a preliminary randomised controlled trial. Physiotherapy. 2012;98:183–8.
55. Company history – Wii. Available at: http://www.nintendo.com/corp/history.jsp
56. Mizner RL, Stevens JE, Snyder-Mackler L. Voluntary activation and decreased force production of the quadriceps femoris muscle after total knee arthroplasty. Phys Ther. 2003;83:359–65.
57. Hurley MV. Quadriceps weakness in osteoarthritis. Curr Opin Rheumatol. 1998;10:246–50.
58. Gibson JNA, Morrison WL, Scrimgeour CM, Smith K, Stoward PJ, Rennie MJ. Effects of therapeutic percutaneous electrical stimulation of atrophic human quadriceps on muscle composition, protein synthesis and contractile properties. Eur J Clin Invest. 1989; 19:206–12.
59. Martin TP, Gundersen LA, Blevins FT, Coutts RD. The influence of functional electrical stimulation on the properties of vastus lateralis fibres following total knee arthroplasty. Scand J Rehabil Med. 1991;23: 207–10.
60. Thomas AC, Stevens-Lapsley JE. Importance of attenuating quadriceps activation deficits after total knee arthroplasty. Exerc Sport Sci Rev. 2012;40:95–101.
61. Stevens JE, Mizner RL, Snyder-Mackler L. Neuromuscular electrical stimulation for quadriceps muscle strengthening after bilateral total knee arthroplasty: a case series. J Orthop Sports Phys Ther. 2004;34:21–9.
62. Young A. The relative isometric strength of type I and type II muscle fibres in the human quadriceps. Clin Physiol. 1984;4:23–32.
63. Gotlin RS, Hershkowitz S, Juris PM, Gonzalez EG, Scott N, Insall JN. Electrical stimulation effect on extensor lag and length of hospital stay after total knee arthroplasty. Arch Phys Med Rehabil. 1994;75:957–9.
64. Avramidis K, Strike PW, Taylor PN, Swain ID. Effectiveness of electric stimulation of the vastus medialis muscle in the rehabilitation of patients after total knee arthroplasty. Arch Phys Med Rehabil. 2003;84:1850–3.
65. Avramidis K, Karachalios T, Popotonasios K, Sacorafas D, Papathanasiades AA, Malizos KN. Does electric stimulation of the vastus medialis muscle influence rehabilitation after total knee replacement? Orthopedics. 2011;34:175.
66. Stevens-Lapsley JE, Balter JE, Wolfe P, Eckhoff DG, Kohrt WM. Early neuromuscular electrical stimulation to improve quadriceps muscle strength after total knee arthroplasty: a randomized controlled trial. Phys Ther. 2012;92:210–26.
67. Stevens-Lapsley, Balter JE, Wolfe P, Eckhoff DG, Schwartz RS, Schenkman M, Kohrt WM. Relationship between intensity of quadriceps muscle neuromuscular electrical stimulation and strength recovery after total knee arthroplasty. Phys Ther. 2012;92:1187–96.
68. Rajan RA, Pack Y, Jackson H, Gillies C, Asirvatham R. No need for outpatient physiotherapy following total knee arthroplasty. A randomized trial of 120 patients. Acta Orthop Scand. 2004;75:71–3.
69. Mockford BJ, Thompson NW, Humphreys P, Beverland DE. Does a standard outpatient physiotherapy regime improve the range of knee motion after primary total knee arthroplasty? J Arthroplasty. 2008;23:1110–4.
70. Kramer JF, Speechley M, Bourne R, Rorabeck C, Vaz M. Comparison of clinic- and home-based rehabilitation programs after total knee arthroplasty. Clin Orthop. 2003;410:225–34.
71. Madsen M, Larsen K, Madsen IK, Søe H, Hansen TB. Late group-based rehabilitation has no advantages compared with supervised home-exercises after total knee arthroplasty. Dan Med J. 2013;60:A4607.
72. Russell TG, Buttrum P, Cert G, Wootton R, Jull GA. Internet-based outpatient telerehabilitation for patients following total knee arthroplasty. A randomized controlled trial. J Bone Joint Surg Am. 2011;93A:113–20.
73. Kauppila AM, Kyllönen E, Ohtonen P, Hämäläinen M, Mikkonen P, Laine V, Siira P, Mäki- Heikkilä P, Sintonen H, Leppilahti J, Arokoski JPA. Multidisciplinary rehabilitation after primary total knee arthroplasty: a randomized controlled study of its effects on functional capacity and quality of life. Clin Rehabil. 2010;24:398–411.