The effects and safety of telerehabilitation in patients with lower-limb joint replacement: A systematic review and narrative synthesis

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Abstract

Introduction: As the number of patients undergoing primary lower-limb joint replacement has risen continuously, hospital-based healthcare resources have become limited. Delivery of any ongoing rehabilitation is needed to adapt to this trend. This systematic literature aimed to examine the effects and safety of telerehabilitation in patients with lower-limb joint replacement.

Methods: A systematic review of randomized controlled trials was conducted according to procedures by the Joanna Briggs Institute. Studies published prior February 2020 were identified from Medline Ovid, Scopus, Ebsco Databases, and Web of Science. Reference lists of relevant studies were also manually checked to find additional studies. Two researchers conducted study selection separately. The JBI Critical Appraisal Checklist for Randomized Controlled Trials was used to evaluate the quality of the relevant studies published. A narrative synthesis was used to report the results while effect sizes were estimated for different outcomes.

Results: Nine studies with 1,266 patients were included. Study quality was predominantly affected by the lack of blinding. The patients who completed telerehabilitation showed an improvement in physical functioning that was similar to that of patients completing conventional in-person outpatient physical therapy without an increase in adverse events or resource utilization. The effect of telerehabilitation on physical functioning, however, was assessed as heterogeneous and moderate-to low-quality evidence.

Discussion: Telerehabilitation is a practical alternative to conventional in-person outpatient physical therapy in patients with lower-limb joint replacement. However, more robust studies are needed in order to build evidence about telerehabilitation.

Keywords: total knee arthroplasty, total knee arthroplasty, systematic literature review, telerehabilitation

Introduction

The demand and costs of total hip arthroplasty (THA) and total knee arthroplasty (TKA) have increased significantly over the past decade. At the same time, hospital-based healthcare and community-based rehabilitation resources have been restricted. [1] In addition, rapid discharge after lower-limb joint replacement is currently common: the average length of a hospital stay has decreased clearly from five days to under four days in patients with THA and from two days to 1.3 days in patients with TKA due to the fast-track discharge methodology and other accelerated discharge methodologies. [2-5]

Physical rehabilitation after lower-limb joint replacement is an essential component of treatment as it helps to improve functional outcomes and promotes the patients' return to their daily activities. [6] Exercise-based rehabilitation generally begins in the hospital and continues after discharge at home and in outpatient clinics. *Telerehabilitation* is a generic term that refers to the remote delivery of physical rehabilitation services (e.g., assessment, monitoring, intervention, supervision, education, consultation, counselling) using information and telecommunication technologies. [7] In addition, telerehabilitation may substitute for, or complement, conventional face-to-face approaches.

The use of telerehabilitation may offer a possible technology-based approach to meeting the increased demands of THA/TKA patient care. In the matter of fact, the usage of the Internet in patients with orthopedic conditions has increased rapidly, particularly in developed countries. [8,9] At the same time, telerehabilitation has been used to deliver ongoing rehabilitation, primarily in cardiac, neurological and physiotherapy rehabilitation to reduce patient hospitalization times and costs to both patients and healthcare providers. [10-13]

In literature, three systematic literature reviews have compared the effects of home-based rehabilitation program (e.g., community physiotherapist visit, rehabilitation at home, monitored by periodic telephone calls, monitored home exercise) with hospital-based (e.g., clinic-, hospital-, inpatient and outpatient) rehabilitation and Internet-based telerehabilitation with conventional face-to-face rehabilitation in patients with in patients with TKA. [7, 14-15] According to their findings, home-based rehabilitation and telerehabilitation have been comparable to conventional care and are thus a significant alternative for patients with TKA, especially in sparsely populated areas. [7, 14,15]

However, there is a gap in evidence regarding the optimal levels and methods required to maximize outcomes. [16] In addition, the effects and safety of telerehabilitation with conventional in-person outpatient physical therapy in patients with THA is unknown. Thus, a focused systematic review was conducted to examine both the effects of telerehabilitation on physical functioning and resource utilization in patients following discharge from hospital after TKA and THA and the safety of the telerehabilitation.

Methods

This literature review was conducted according the Joanna Briggs Institute's guidelines [17] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement for systematic reviews (Supplementary File 1) [18].

Search strategy

The systematic review was conducted in February 2020. First, a preliminary investigation of the previous literature was conducted in Melinda and Medline Ovid to determine whether randomized controlled trials (RCTs) were available on the topic of interest and to identify initial keywords, synonyms and variants of the search and index terms. [17] Secondly, all published studies were identified from Medline Ovid, Scopus, Ebsco Databases, and Web of Science. Reference lists of relevant studies were also manually checked to find additional studies. The search strategy and key search terms (see Appendix 1) were developed in cooperation with an information specialist by breaking down the research question into smaller components (PICOS): population (patients with THA/TKA), interventions (telerehabilitation), comparators (conventional in-person outpatient physical therapy), outcomes (e.g., physical functioning, adverse events, resource utilization), and study design (RCT). Literature review was restricted to adults (≥18 years old), and only studies published in Finnish, English, or Swedish were included. Studies evaluating assessment tools, conference abstracts, reporting preliminary results, and unpublished studies were excluded.

Review method

The review was conducted in three phases. [17] In the first phase (N =985), duplicated studies (n =541) within Medline Ovid, Scopus, Ebsco Databases, and Web of Science were excluded (Figure 1). In the second phase, two reviewers with methodological and content expertise screened the studies by evaluating their titles (n =444) and abstracts (n =136) against the predetermined inclusion and exclusion criteria. [19] In the third phase, the full-texts (n =13) of potentially eligible studies were read and further evaluated by the same independent reviewers. After nine non-randomized studies and one feasibility study were excluded, a total of nine studies were included in this review.

Quality appraisal

Two reviewers assessed the quality (e.g., selection bias, blinding, data collection methods, withdrawals and drop-outs, intervention integrity and analyses) of the articles separately. They used the JBI's Critical Appraisal Checklist for Randomized Controlled Trials. [17] The total quality score ranged from 0–13 points with one point being assigned if the item was mentioned in the study and no points being assigned if the item was not mentioned or if it was unclear. Due to the lack of studies, all the assessed studies were included in the final review.

Data analysis

Data were extracted by the corresponding author; meanwhile, the extracted data was crosschecked by another author (see Table 1). The primary outcome was physical functioning. Additional outcomes were adverse events and resource utilization. Cohen's *d* values were used to measure the effect size of each studied outcome. We used the recommendations of Cohen to interpret effect sizes; *d* values of 0.2 to 0.5 indicate a small effect, the values 0.5 to 0.8 indicate a moderate effect and a value of 0.8 or more indicates a large effect. [20] In the current study, negative values of *d* indicate that the telerehabilitation group has had a better outcome whereas positive values of *d* indicate that conventional in-person outpatient physical therapy is has had a better outcome. Stata version 15 was used for the forest plots (StataCorp, 2017).

RESULTS

The detailed characteristics of the included studies are displayed in Table 1. The years of publication ranged from 2011 to 2019.

A general description of the studies included

A total of 1,266 participants with TKA and THA were randomized to complete either telerehabilitation or conventional in-person outpatient physical therapy. The sample size ranged from 29 participants to 389 participants. In light of geographical location, two studies were conducted in Canada, [21,23] two in the USA, [24, 25] one in Spain, [26] one in Australia, [27] one in Germany, [28] and one in China [29]. Of the nine studies, three were multi-site studies. [22, 23, 29] The mean age of the participants ranged from 54.5 to 73.3 years old.

All the participants were recruited from hospitals. Patients were eligible for inclusion if they were adult patients (≤75 to <85 years old);[24, 29] if they were undergoing or had undergone elective (unicompartmental or unilateral) primary [26, 27] after a diagnosis of osteoarthritis; [21-23] if they were returning back home after hospital discharge [21-24] with an active range of motion (ROM) and the ability to walk with the use of a walking aid; [26] if they used a smartphone; [25, 29] if they were living in an area served by high-speed Internet services; [21-24] and if they were living within a one-hour driving distance from the treating hospital. [21-23]

A description of the intervention

The included studies were comparing 1) an Internet-based real-time two-way videoconferencing systems; [21-23, 27] 2) an interactive virtual telerehabilitation (IVT) software-hardware platform; [26] 3) an asynchronous video-based software platform (CaptureProof app); 4) an Internet-based orthopedic care platform (e.g., StreaMD); [25, 29] and 5) an app-based active muscle training system (GenuSport) [28] for conventional face-to-face in-person outpatient physical therapy (see Table 2). The duration of the series of rehabilitation (45–60 minute per session) ranged from 2 to 8 weeks (Table 2). In the study of Bini and Mahajan (2017), however, rehabilitation was continued until the patient or therapist chose to end the intervention. [24] None of the studies recorded any theoretical basis for the intervention.

Quality appraisal

An overview of the quality appraisal of the included studies is displayed in Table 3. A biased selection process was reported in three out of nine of the included studies.[21, 24, 25] The participants and those delivering treatment were not blinded due to the nature of treatment. [21-27, 29] In addition, the blinding of outcome assessors was insufficiently reported in five of the nine included studies. [21, 24, 27-29] Furthermore, intention-to-treat analysis [21-24, 27, 29] as well as a power-analysis [23, 24, 27, 29] were rarely reported. The exposure to other treatment, and studies of the impact of not following up on the results were insufficiently reported.

Efficacy outcomes

The studies reported outcomes like change in active and/or passive knee flexion and extension [21, 26-27], ROM extension and flexion of the involved knee, [21, 22, 25, 28] change in quadriceps strength, [26, 27] change in hamstring strength, [26] change in isometric strength, [22] Timed Up and Go (TUG) test, [26, 27, 28] a timed stair test, [21, 22] change in Gait Assessment Rating Scale, [27] change in limb girth of knee and calf , a six-minute walk test, a 10-minute walk test, and a chair stand test. [22, 27, 28] Active and passive knee flexion and extension, ROM extension and flexion, and strengths were assessed objectively using a goniometer or dynamometer.

Short- and long-term symptoms and functional improvements were measured using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), [21, 22, 26, 27] the Patient-Specific Functional Scale (PSFS), [27] the Knee Injury and Osteoarthritis Outcome Score (KOOS), the KOOS Physical Function Short Form (KOOS-PS), the Health Survey, [22, 24, 28] and the Knee Society Score (KSS). [28] Hip function was assessed using the Harris hip score. [29]

Change in the intensity of pain was measured using a Visual Analogue Scale (VAS) for pain, [24, 27] the numeric rating scale (NRS), [28] and the consumption of narcotic drugs (days). [25] Quality of life was assessed using the quality-of-life SF-36 scale (MOS SF-36) while activities of daily living were assessed using the Barthel Index. [29]

Only one study described the frequency of adverse events in patients with TKA. [22] The effects of telerehabilitation on resource utilization were assessed using direct and indirect costs, as well as the length of stay, [28] the mean duration and the total number of visits and phone calls. [23, 24, 25] Repeated measurements were conducted prior to intervention (the baseline) and post intervention (e.g., at the end of treatment, six weeks after discharge or 2–4 months after discharge).

Change in active and passive extension (°). Four studies evaluated this outcome. [21, 26, 27, 28] Compared with the conventional care, telerehabilitation showed no significant difference in active and passive (SMD -0.06, 95% CI -0.55 to 0.43) knee extension (Figure 2).

Change in active knee flexion (°). Three studies evaluated this outcome. [21, 26, 27] Compared with the conventional care, telerehabilitation showed no significant difference in active knee flexion (Figure 2).

Range of motion (°). Four studies evaluated this outcome. [21, 22, 25, 27] Compared with the conventional care, telerehabilitation showed no significant difference in ROM extension and flexion of the involved knee (Figure 2). However, in the study of Campbell et al., the difference was maintained only for three weeks.

Change in strength (kg, nm). Three separate studies evaluated this outcome. [22, 26, 27] Compared with the conventional care, telerehabilitation showed no significant difference in the quadriceps strength or isometric strength of the involved knee in flexion or extension. Conflicting results were observed related to hamstring strength (Figure 3).[22, 26]

Change in Timed Up and Go test (sec). Three studies evaluated this outcome. [26, 27, 28] Conflicting results were observed related to TUG test (Figure 3).

Six-minute walk test (m). Only one study evaluated this outcome. [22] Compared with the conventional care, telerehabilitation showed no significant difference in the six-minute walk test after 4-months follow-up (SMD -2.34, 95% CI -2.70 to -1.97).

10-meter walk test (m/s). Only one study evaluated this outcome. [28] Compared with conventional care, telerehabilitation showed a significant difference in the 10-meter walking test (Figure 3).

Change in clinical gait (points). Only one study evaluated this outcome. [27] Compared with the conventional care, telerehabilitation showed no significant difference in clinical gait (SMD -0.14, 95% CI -0.63 to 0.35).

Change in limb girth (cm). Two studies evaluated this outcome. [27, 28] Compared with the conventional care, telerehabilitation showed no significant difference in limb girth of knee and calf (Figure 3).

Timed stair test (sec). Two studies evaluated this outcome. [21, 22] Compared with the conventional care, telerehabilitation showed no significant difference in the timed stair test after 4-months follow-up (SMD -2.44, 95% CI -2.81 to -2.07)

Chair stand test (n). Only one study evaluated this outcome. [28] Compared with the conventional care, telerehabilitation showed no significant difference in the 30-s Chair Stand Test (see Table 1).

Change in the Patient-Specific Functional Scale. Only one study evaluated this outcome. [27] Compared with the conventional care, telerehabilitation showed significant difference in the PSFS (SMD -0.7, 95% CI -1.20 to -0.19).

Change in the Western Ontario and McMaster Universities Osteoarthritis Index. Three studies evaluated this outcome. [22, 25, 27] Compared with the conventional care, telerehabilitation showed significant difference in the total score of WOMAC [26] while in the study of Russel et al. (2011) [27], telerehabilitation only showed significant improvements in the stiffness subscale of WOMAC (SMD -0.61, CI95% -1.11 to -0.12). On the other hand, in the study of Moffet et al. (2015) [22], the telerehabilitation showed no significant difference in the total score of WOMAC (SMD -0.69, 95% CI -0.98 to -0.41) when compared with conventional in-person outpatient physical therapy (Figure 4).

Knee Injury and Osteoarthritis Outcome Score. Three studies evaluated this outcome. [22, 26, 28] Compared with the conventional care, telerehabilitation showed no significant difference in the KOOS (Figure 4).

Knee Society Score. One study evaluated this outcome. [28] Compared with conventional care, telerehabilitation showed significant difference in the KSS (Figure 4).

Harris hip score. One study evaluated this outcome. [29] Compared with the conventional care, telerehabilitation showed significant difference in the hip function(Figure 4) .

Change in pain. Five studies evaluated this outcome. [24-28] Compared with the conventional care, telerehabilitation showed no significant difference in the intensity of VAS pain (Figure 5). Telerehabilitation showed a significant difference in the NRS score at rest and in motion [25] as well as in the consumption of narcotic drugs (see Table 1). [28]

Quality of life: One study evaluated this outcome. [29] Compared with the conventional care, telerehabilitation showed significant difference in the MOS SF-36 scale (Figure 4).

Activities of daily living. One study evaluated this outcome. [29] Compared with conventional care, telerehabilitation showed a significant difference in the Barthel Index (see Table 1).

Adverse events. Only one study evaluated this outcome. [22] Compared with the conventional care, telerehabilitation showed no significant difference in the incidence of adverse events.

Resource utilization. Four studies evaluated this outcome. [23-25, 28] Compared with the conventional in-person outpatient physical therapy, telerehabilitation showed a significant decrease in the total cost (MD: \$-263; 95% CI: \$-382 to \$143; $p < 0.001$; see Table 1). In addition, telerehabilitation showed a significant decrease in the cost per treatment (MD: \$-12.09; 95% CI: \$-20.90 to \$-3.20; $p = 0.08$). The difference in the costs, however, was only significant when the distance from home to the healthcare centre was more than 30 km (\$81.3 [$SD = 13.19$] vs. \$102.7 [$SD = 19.5$], $p = 0.02$).

Compared with the conventional in-person outpatient physical therapy, telerehabilitation showed significant difference in the total number of visits to physical therapy (see Table 1). In addition, telerehabilitation showed a significant difference in the total number of calls to the office. [25] Compared with conventional care, telerehabilitation showed no significant difference in the length of stay. [28]

DISCUSSION

A systematic literature review was undertaken to establish the most recent evidence about the effects and safety of telerehabilitation on physical functioning and resource utilization in patients with TKA/THA. According to our findings, telerehabilitation is as effective as conventional in-person outpatient physical therapy in improving active and passive knee flexion and extension; ROM extension and flexion of the involved knee; limb girth; clinical gait; timed stair, chair stand, and six-minute walk tests; the quadriceps and isometric strength of the involved knee; and KOOS.

Participants in the telerehabilitation group received all their physical rehabilitation after discharge via complex and heterogeneous methods. Real-time interaction with a physical therapist across a low-bandwidth Internet-based videoconferencing system was the most frequent method for telerehabilitation. It must be noted, however, that the use of smartphones has increased since 2018. However, in line with the findings of Snell et al., there is still a gap in evidence regarding the optimal levels and the methods required to maximize outcomes.[16] In addition, there is a lack of intervention studies covering the whole surgical care journey.

Although the following measures were evaluated in only one study, compared with the conventional in-person outpatient physical therapy, telerehabilitation showed significant improvement on the PSFS, [27] the 10-meter walking test, [28] the knee society score, [28] the Harris hip score; [28] quality of life, [29] and activities of daily living.[29] These improvements can be attributed to the ease of the equipment for patients in their home, which leads to unrestricted access to and allows patients to continue their therapy more effectively. This would have also resulted in a higher compliance with the home exercise program [27] and a longer duration of exercise [24] in the telerehabilitation group compared to the in-person outpatient physical therapy group.

In line with recent meta-analyses [14-15], conflicting results were observed related to WOMAC [21-22, 26-27] and pain relief. [24-28] The effect of telerehabilitation on pain was small whereas the effect of telerehabilitation on stiffness, function and total score was moderate (See Figure 3). In addition, conflicting results were observed regarding the TUG test [26-27] and hamstring strength. [22, 26]

Compared with the conventional in-person outpatient physical therapy, telerehabilitation showed no significant difference in active and passive knee extension or flexion [21, 26–28], ROM extension and flexion of the involved knee, [21, 22, 25,

[27] the quadriceps and isometric strength of the involved knee [22, 26, 27], the KOOS, [22, 26, 28] limb girth, [27, 28] clinical gait, [27] the six-minute walk test, [22] the chair stand test, [28] and the timed stair test. [21-22]

In the recent meta-analyses, conflicting results have been observed related to pain relief. [14-15]Unexpectedly, however, the intensity of pain has been lowered in hospital-based group whereas the movement of knee has been superior in home-based rehabilitation group. [14] In the study of Tousignant et al., patients in conventional in-person outpatient physical therapy had less bodily pain than patients in a telerehabilitation group two months after the end of treatment when compared with their pain before treatment. [21]

In line with telephone-delivered interventions [30–31], the use of telerehabilitation has been safe; the rate of missed adverse events was zero among patients who completed telerehabilitation and conventional in-person outpatient physical therapy. [22] In addition, telephone-delivered interventions have decreased the need for rehabilitation sessions in an outpatient clinic [28] and reduced the amount of postoperative complications and, thus, reduced the resource utilization of the community health system and improved patient-reported outcomes. [32–33]

A strict recommendation for methods decreasing resource utilization cannot be made due to the lack of studies. The mean cost of a single session, cost per treatment, and the total rehabilitation cost were lower among patients who completed telerehabilitation compared to patients completing conventional in-person outpatient physical therapy. [23–25, 28] Additionally, Bini & Mahajan reported that the mean duration of exercise and the total number of visits to physical therapy were lower among patients who completed telerehabilitation. [24] The recent meta-analysis by Li et al. revealed, however, that home- and hospital-based rehabilitation programs have similar costs. [14] The variability of results between studies might be due to the variety of outcome measures. Moreover, different healthcare systems may cause a markable effect on the resource utilization. In the future, a more holistic view should be taken into account when planning to measure the social benefits of telerehabilitation from the both clinician and patient perspectives. [34]

Several limitations of this literature review need to be addressed. Firstly, of the nine studies reviewed, five were low in methodological quality while four were of moderate quality, which limits the conclusions that can be drawn from the synthesis of the findings from the included studies. In addition, meta-analysis was not possible due to heterogeneity amongst the included studies. Secondly, conflicting results were obtained, which might be due to the lack of a universal method for outcome measures. Thirdly, the generalization of results may not be appropriate in all cases because the studies were conducted in different health-care settings with differences in the socioeconomic status of the patients. Fourthly, the overall, the reporting of results was insufficient according to the internal validity. Fifthly, there is still controversy regarding the optimal levels and methods required to maximize patient outcomes and resource utilization. In addition, a strict recommendation for methods promoting functional improvements cannot be made as the outcome measures varied and statistical heterogeneity exists between the studies.

CONCLUSION

The patients who completed telerehabilitation showed improvement in physical functioning that was similar to that of patients completing conventional in-person outpatient physical therapy without an increase in adverse events or resource utilization. Telerehabilitation is a practical alternative to conventional in-person outpatient physical therapy in patients with lower-limb joint replacement. More robust studies, however, are needed to build evidence about telerehabilitation

Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Table 1. The study characteristics of the included studies related to telerehabilitation.

Author, year	**Study design and setting**	**Participants**	**Intervention and dosage**	**Control and dosage**	**Outcome measures**	**Results (telerehabilitation vs. conventional in-person outpatient physical therapy)**
Bini & Mahajan, 2017	RCT; Kaiser Permanente Oakland Medical Center, USA. April 2014 to April 2015.	An experimental group (*n* =14) and a control group (*n* =15); patients with TKR. Mean age of 62.9 years in intervention group and 63.6 years in control group.	An asynchronous video-based software platform on a mobile device. A 2-week program.	In-person outpatient physical therapy visits.	Measurements before and 3 months after surgery.	- KOOS (change); mean (SD): Physical Functioning Short Form: -17.6 (17.2) vs. -17.3 (14.2), p =0.40 - VAS for pain score (change); mean (SD): -3.4 (2.7) vs. -4.0 (3.2), p =0.35 - Duration of exercise (minutes); mean: 47 vs. 60 - Number of additional in-person visits (%): 3 (29) vs. 4 (20) - Total number of visits to the physical therapy for one-on-one visits: 17 vs. 31 - Total number of visits to the physical therapy for group visits: 3 vs. 66
Campbell et al., 2019	RCT; Rush University Medical Center, USA. November 2016 to October 2017.	An experimental group (*n* =76) and a control group (*n* =83); patients with TKA or THA. Mean age of 61.0 years in intervention group and 59.5 years in control group.	An automated short message service (StreaMD) with scheduled text and video messages hosted on a HIPAA-compliant server.	Traditional preoperative education with preoperative clinic appointment and a supply of perioperative instructions.	Demographics, measurements 3 and 6 weeks after the surgical procedure.	- Time exercising per day; minutes (SD): 46.4 (17.4) vs. 37.7 (16.3), p <0.001 - VAS mood score; points (SD): 7.5 (1.8) vs. 6.5 (1.7), p <0.001 - Time taking narcotics; days (SD): 22.5 (13.4) vs. 32.4 (11.8), p >0.001 - Extension (6-week); degree (SD): 1.6 (2.8) vs. 2.6 (5.5), p=0.295 - Flexion (6-week); degree (SD): 111.9 (13.3) vs. 108.0 (12.8), p=0.161 - Total calls to the office: 0.6 (0.8) vs. 2.6 (3.4), p <0.001

Hardt et al., 2018	RCT; single tertiary healthcare center, Germany.
	
	April to October 2016.
		An experimental group (*n* =27) and a control group (*n* =33); patients with TKA.
		
		Mean age of 63.3 years in intervention group and 67.6 years in control group.
			App-based feedback-controlled active muscle training system (GenuSport).	Conventional program.	NR	- Active ROM; degree (SD): 78 (12) vs. 67 (18), p = 0.038
						- Pain at rest; NRS (SD): 2 (1) vs. 4 (2), p = 0.01
						- Pain in motion; NRS (SD): 4 (1) vs. 5 (1), p = 0.002
						- GenuSport strength; kg (SD): 17.2 (5.3) vs. 14.9 (5.6)
						- Passive ROM; degree (SD): 85 (11) vs. 84 (11)
						- Length of stay; days (SD): 6.6 (1) vs. 6.9 (1)
						- Mean knee circumference; cm (SD): 47 (4.5) vs. 48 (5.5)
						- TUG test; sec (SD): 17.7 (8.2) vs. 26.6 (17.1)
						- 10-m walking test; m/s (SD): 0.6 (SD 0.3) vs. 0.5 (0.2), p = 0.032
						- Chair stand test; n: 4 (5) vs. 3 (5)
						- KOOS scores (%)
						    ○ Symptoms: 62 (15) vs. 58 (13)
						    ○ Pain: 56 (14) vs. 50 (18)
						    ○ Activities of daily living: 54 (17) vs. 42 (17), p = 0.037
						    ○ Sport: 10 (12) vs. 5 (8)
						    ○ Quality of life: 30 (17) vs. 6 (8)
						- KSS Knee: 73 (10) vs. 59 (15), p <0.001
						- KSS Function: 45 (13) vs. 37 (16), p = 0.011

Moffet et al., 2015	RCT; Eight hospitals in three Quebec regions in Canada.	An experimental group (*n* =98) and a control group (*n* =100); patients with TKA. Mean age of 65 (SD 8) years in intervention group and 67 (SD 8) years in control group.	A low-bandwidth internet-based telerehabilitation program. An 8-week program.	Face-to-face rehabilitation.	Measurements before and after (2- and 4-month) discharge.	- KOOS (change); % (SD), MD (95% CI): • Symptoms: 74.8 (1.5) vs. 71.9 (1.5), -2.6 (-7.0, 1.8) • Pain: 80.1 (1.4) vs. 78.1 (1.4), -1.8 (-6.2, 2.5) • Activities of daily living: 85.7 (1.3) vs. 84.2 (1.3), -0.8 (-4.7, 3.0) • Sports and recreational activities: 30.9 (2.0) vs. 29.8 (1.9), -1.9 (-8.8, 5.0) • Quality of life: 69.5 (1.9) vs. 69.0 (1.9), -0.4 (-6.8, 6.1) - WOMAC Index (change); % (SD) • Pain: 84.0 (1.4) vs. 82.8 (1.4), -0.7 (-4.8, 3.4) • Stiffness: 71.0 (2.0) vs. 72.1 (1.9), 0.7 (-5.2, 6.5) • Function: 84.9 (1.3) vs. 83.9 (1.3), -0.4 (-4.3, 3.4) • Total: 83.5 (1.3) vs. 82.6 (1.3), -0.1 (-3.9, 3.7) - ROM flexion (change); deg (SD), MD (95% CI): 111.5 (1.0) vs. 112.4 (1.0), 1.1 (-2.1, 4.3) - ROM extension (change); deg (SD), MD (95% CI): -3.6 (0.4) vs. -3.4 (0.4), 0.01 (-1.0, 1.0) - Six-minute walk test (change); m (SD), MD (95% CI): 407.5 (6.0) vs. 396.3 (5.9), -7.4 (-27.8, 13.1) - Timed stair test (change); (SD), MD (95% CI): 26.6 (1.4) vs. 29.9 (1.3), -1.2 (-4.8, 2.4)
Piqueras et al., 2013	RCT; An acute-care university hospital in Barcelona, Spain. November 2008 to December 2010.	An experimental group (*n* = 68) and a control group (*n* = 60); patients with TKA. Mean age of 73.3 (SD 6.5) years.	An interactive virtual telerehabilitation system. A 2-week program.	Conventional program.	Measurements before surgery, at the end of the rehabilitation program, and at 3-month follow-up.	- Active knee flexion (change); deg (SD): 18.16 (9.71) vs. 15.63 (8.82), p =0.193 - Active knee extension (change); deg (SD): 0.8 (3.3) vs. 0.8 (3.3), p =0.48 - Quadriceps strength (change); kg (SD): 8.5 (5.0) vs. 5.89 (5.2), p =0.018 - Hamstring strength (change); kg (SD): 2.9 (3.3) vs. 2.3 (3.3), p =0.35 - TUG test (change); sec (SD): -7.0 (6.3) vs. -10.9 (8.7), p =0.020 - VAS for pain score (change); points (SD): -1.8 (2.5) vs. -2.3 (2.0), p =0.28
Russell et al., 2011	RCT; A city hospital in Brisbane, Australia.	An experimental group (*n* =31) and a control group (*n* =34); patients with TKA. Mean age of 66.2 (SD 8.4) years in intervention group and 69.6 (SD 7.2) years in control group.	A low-bandwidth internet-based telerehabilitation program. A 6-week program.	Conventional outpatient physical therapy.	Measurements at baseline and 6 weeks after.	- Patient-Specific Functional Scale; points (mean, SD), MD (95% CI): 5.1 (1.4) vs. 4.0 (1.7), 1.1 (-1.9, -0.3), p =0.04 - WOMAC Index (change); mean (SD), MD (95% CI): • Pain: 3.0 (2.3) vs. 2.2 (1.8), 0.8 (-0.3, 1.8), p =0.24 • Stiffness: 3.3 (2.3) vs. 1.8 (2.4), 1.5 (0.2, 2.7), p =0.04 • Function: 3.5 (2.4) vs. 2.5 (1.8), 1.1 (-0.0, 2.1), p =0.18 • Total: 3.3 (2.0) vs. 2.2 (1.7), 1.1 (0.4, 2.1), p =0.08 - Active flexion range (deg); mean (SD), MD (95% CI): 19.8 (10.8) vs. 17.8 (12.3), -2.0 (-7.9, 3.9), p =0.61

						- Active knee extension (deg); mean (SD), MD (95% CI): 3.5 (3.5) vs. 3.6 (3.9), -0.2 (-2.1, 1.7), $p > 0.8$ - Passive flexion range (deg); mean (SD), MD (95% CI): 17.9 (10.5) vs. 17.2 (13.9), -0.7 (-7.0. 5.5), $p > 0.8$ - Quadriceps strength (deg); mean (SD), MD (95% CI): 9.2 (7.3) vs. 5.7 (5.2), 3.5 (0.4, 6.7), $p = 0.23$ - Limb girth knee (cm); mean (SD), MD (95% CI): 2.2 (1.8) vs. 2.4 (1.9), -0.15 (-1.1, 0.8), $p > 0.9$ - Limb girth calf (cm); mean (SD), MD (95% CI): 1.04 (1.48) vs. 2.12 (2.90), -1.1 (-2.3, 0.1), $p = 0.39$ - TUG test (sec); mean (SD), MD (95% CI): 16.3 (10.9) vs. 12.2 (10.1), 4.2 (-1.2, 9.5), $p = 0.21$ - Gait (points), mean (SD); 7.7 (4.4) vs. 6.9 (6.0), MD (95% CI) 0.7 (-1.9, 3.4), $p = 0.68$ - VAS for pain score (points); mean (SD): 3.1 (1.6) vs. 3.3 (1.3), MD (95% CI) -0.28 (-0.9, 0.5), $p > 0.9$ - Compliance with the home exercise program; mean (SD): 2.2. (0.5) vs. 1.7 (0.8), $p = 0.12$
Tousignant et al., 2011	RCT; The University Hospital of Sherbrooke and the University Hospital of Quebec, Canada.	An experimental group (*n* =21) and a control group (*n* =20); patients with TKA. Mean age of 66 (SD 10) years in intervention group and 66 (SD 13) years in control group.	A low-bandwidth internet-based telerehabilitation program. An 8-week program.	Conventional rehabilitation.	Measurements prior to the end of treatment (T1), at the end of treatment (T2), and four months afterwards (T3).	- Participants in the control group showed more improvement than the experimental group in the total score of WOMAC (a difference of 8.1 points) - Participants from the control group showed more improvement than the experimental group in the WOMAC difficulty section ($p = 0.047$) - Participants in the control group had better physical functioning two months after treatment ($p = 0.019$) and less bodily pain two months after treatment ($p = 0.013$)
Tousignant et al., 2015	RCT; Eight hospitals in the province of Quebec, Canada.	An experimental group (*n* =97) and a control group (*n* =100); patients with TKA. Mean age of 65 (SD 8) years in intervention group and 67 (SD 8) years in control group.	A low-bandwidth internet-based telerehabilitation program. An 8-week program.	Conventional rehabilitation.	Measurements at baseline (E1), 1–2 days before discharge (E2), 2 months postdischarge (E3), and 4 months postdischarge (E4).	- Total cost ($); mean (SD), MD (95% CI): 1224 (241) vs. 1487 (553), -263 (-382 to -143), $p < 0.001$ - Cost per treatment ($); mean (SD), MD (95% CI): 81.0 (26.6) vs. 93.1 (35.7), -12.1 (-20.9 to -3.3), $p = 0.08$

Wang et al., 2018	RCT; 18 hospitals in the province of Jiangsu, China. April to October 2016.	An experimental group (*n* =194) and a control group (*n* =195); patients with THA. Mean age of 54.5 (SD 13.6) years in intervention group and 56.8 (SD 13.9) years in control group.	Internet-based, orthopedic care platform with interactive tools.	Routine nursing care.	Measurements at admission and 3 months and 6 months after discharge.	- Harris hip score; mean (SD): 92.7 (3.7) vs. 86.6 (4.6), $p < 0.001$ - MOS SF-36; mean (SD): 119.0 (10.5) vs. 112.3 (97.2), $p < 0.001$ - Activities of daily living; mean (SD): 93.9 (4.7) vs. 88.9 (5.8), $p < 0.001$
HIPAA = Health Insurance Portability and Accountability Act, KOOS = Knee Injury and Osteoarthritis Outcome Score, KOOS-PS = Knee Injury and Osteoarthritis Outcome Score Physical Function Short Form, MD = mean difference, Medical Outcomes Study 36-item Short-Form Health Survey = MOS SF-36, NR = not reported, RCT = randomized controlled trial, ROM = range of motion, SD = standard deviation, THA, total hip arthroplasty, TKR = total knee replacement, TKA = total knee arthroplasty, TUG tests = Timed Up and Go tests, VAS = Visual Analogue Scale, WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index.						

Table 2. A description of the interventions.

Author, year	Intervention	Duration (weeks)	Dosage	Supervised exercises	Material and other support
Bini & Mahajan, 2017	An asynchronous video-based software platform on a mobile device (CaptureProof app) HIPAA compliant platform	2	The CaptureProof app included 23 videos (<3 minutes per video) illustrating the similar exercises taught in the out-patient clinic and had on-screen text-based instruction.	Possibility to send recordings to physical therapists, get feedback, and get more advanced exercise videos based on progress The type, number, and frequency of the exercises were customized to the needs of each patient based on their recovery. In addition, other members of the care team could be brought into the conversation	The CaptureProof app was downloaded onto an iPod Touch Phone or in-person access to technical support was available
Campbell et al., 2019	An automated short message service (StreaMD) with scheduled text and video messages hosted on a HIPAA compliant server	6	The automated text messages included recovery instructions paired with encouraging and empathetic statements, personalized video messages, and short instructional therapy videos.	Patients had the opportunity to receive additional automated, informational responses.	A member of the research team called each patient in both groups 3 days, 2 weeks, and 4–5 weeks after the surgical procedure.
Hardt et al., 2018	App-based feedback-controlled active muscle training system (GenuSport)	NR	The training program consists of two different games.	NR	NR
Moffet et al., 2015	Real-time interaction with a physical therapist across a low-bandwidth Internet-based videoconferencing system The technological platform was based on h264 videoconference codecs (Tandberg 550 MXP; Cisco Systems) with clinician-controlled PTZ cameras and dedicated software allowing real-	8	The intervention's duration and intensity were standardized (16 X 45–60-minute sessions) and based on the recommendations of group experts	Supervised exercises were provided by trained physical therapist during a period of approximately 30 minutes (e.g., mobility, strengthening, function, balance exercises) The intensity and difficulty level of the exercises were increased according to each patient's tolerance and needs	Assessment before and after exercise (e.g., structured interview, observation) Prescription of home exercises to perform on days without supervised sessions, and advices concerning pain control, walking aids, and the return to activities

	time two-way video and audio interaction over the Internet				
Piqueras et al., 2013	Real-time interaction with a physical therapist across an IVT software-hardware platform The IVT kit contained a touch-screen all-in-one computer (ASUS EEE Top 1602), which included a Microsoft-licensed Windows XP Home operating system, wireless sensors to record patients' movement trajectories (WAGYRO) with one low-bandwidth (<200 Mbytes) mobile Internet device, interactive patient application with a 3D avatar, a Web portal for the therapist, and items necessary to perform the exercises (e.g., weights, traps, a stretch band)	2	The standard clinical protocol of TKA rehabilitation for 10 days (10 X 60-minute sessions). Five sessions were performed under a therapist's supervision and 5 sessions were performed at home	Progressive exercise and instruction including knee ROM, gait training, and instructions in negotiating stairs and community-related obstacles The daily pattern of exercises using the IVT under the therapist's supervision	Instructions to continue the exercises routine over the weekend A 3D avatar demonstrated the exercises to be undertaken Contacting the patient via telephone if necessary
Russell et al., 2011)	Real-time interaction with a physical therapist across a low-bandwidth (18-kbit/sec) Internet-based videoconferencing system	6	Weekly treatment sessions (1 X 45-minute sessions) based on a comprehensive home exercise program, which was encouraged to be completed twice daily	A physical therapist administered a rehabilitation program that consisted of self-applied techniques under the guidance of the remote therapist, along with exercises and education	Clinical pathway protocol provided a week-by-week guide Standardized inpatient rehabilitation program
Tousignant et al., 2011	Real-time interaction with a physical therapist across a low-bandwidth Internet-based videoconferencing system (Tandberg 550 MXP), which used an H.264 video codec and incorporated a PTZ camera with a wide-angle lens and omnidirectional microphone Remote-controlled cameras, 50 cm LCD screens and associated software	8	The teletreatment was delivered at a rate of two sessions per week for eight weeks (16 X 60-minute sessions) and designed for functional recovery, based on reducing disabilities and improving function in daily activities through progressive exercises	Functional rehabilitation, progressive exercises, treatment assessment, and recommendations	
Tousignant et al., 2015	Real-time interaction with a physical therapist across a low-bandwidth Internet-based videoconferencing system (Tandberg 550 MXP), which	8	The teletreatment was delivered at a rate of two sessions per week for eight weeks (16 X 60-minute sessions) and designed for functional recovery, based	Functional rehabilitation, progressive exercises, treatment assessment, and recommendations	

	used an H.264 video codec and incorporated a PTZ camera with a wide-angle lens and an omnidirectional microphone		on reducing disabilities and improving function in daily activities through progressive exercises		
Wang et al., 2018	Internet-based, orthopedic care platform with interactive tools including WeChat.	NR	Orthopedic nurse specialist provide personal clinics on their ports with interactive tools (e.g., Clinical Broadcast, Question and Answer Application, Appointment Application, Rehabilitation Exercise). The patient port has interactive tools (e.g., Clinical Broadcast, Question and Answer Application, Appointment Application, Rehabilitation Exercise)	Possibility to send questions (question and answer interaction), upload photographs and videos and an appointment application. Nurse specialist can continuously observe the patients' functional exercise after discharge and promptly solve problems for the patient.	The nurse port has these four functions: Clinical Setting, My Patient, Work Calendar, and Consultation Information. The patient port has these four functions: Clinical Broadcast, Science Learning, Expert Introduction, and Customer Service Help.

HIPAA = Health Insurance Portability and Accountability Act, IVT = interactive virtual telerehabilitation, NEar = not reported, PTZ = pan, tilt, zoom, TKA = total knee arthroplasty

Table 3. Assessment of quality of the methodology of the included studies (Joanna Briggs Institutes' tool for assessing risk of bias).

Author	**Was true randomization used for assignment of participants to treatment groups?**	**Was allocation to treatment groups concealed?**	**Were treatment groups similar at baseline?**	**Were participants blind to treatment assignment?**	**Were those delivering treatment blind to treatment assignment?**	**Were outcome assessors blind to treatment assignment?**	**were treatment groups treated identically other than the intervention of interest?**	**Was follow-up complete and if not, were differences between groups in terms of their follow up adequately descripted and analyzed?**	**Were participants analyzed in the groups to which they were randomized?**	**Were outcomes measured in the same way for treatments groups?**	**Were outcomes measured in a reliable way?**	**Was appropriate statistically analysis used?**	**Was the trial design appropriate, and any deviations from the standard RCT design accounted for in the conduct and analysis of the trial?**	**The assessment of methodological quality**
Bini & Mahajan, 2017	No	Yes	Yes	N/A	N/A	N/A	N/A	Yes	N/A	No	N/A	No	Yes	4
Campbell et al., 2019	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	9
Hardt et al., 2018	Yes	Yes	Yes	Yes	No	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Yes	11
Moffet et al., 2015	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes	N/A	Yes	Yes	9
Piqueras et al., 2013	Yes	Yes	Yes	N/A	N/A	Yes	N/A	Yes	N/A	Yes	Yes	Yes	Yes	9
Russell et al., 2011	Yes	Yes	Yes	N/A	N/A	N/A	N/A	Yes	N/A	Yes	N/A	Yes	Yes	7
Tousignant et al., 2011	No	Yes	Yes	N/A	N/A	N/A	N/A	Yes	N/A	Yes	N/A	No	Yes	5
Tousignant et al., 2015	Yes	Yes	Yes	N/A	N/A	Yes	N/A	Yes	N/A	Yes	Yes	No	Yes	8
Wang et al., 2018	Yes	N/A	Yes	N/A	N/A	N/A	Yes	N/A	N/A	Yes	Yes	Yes	Yes	7

Abbreviations: N/A, not available

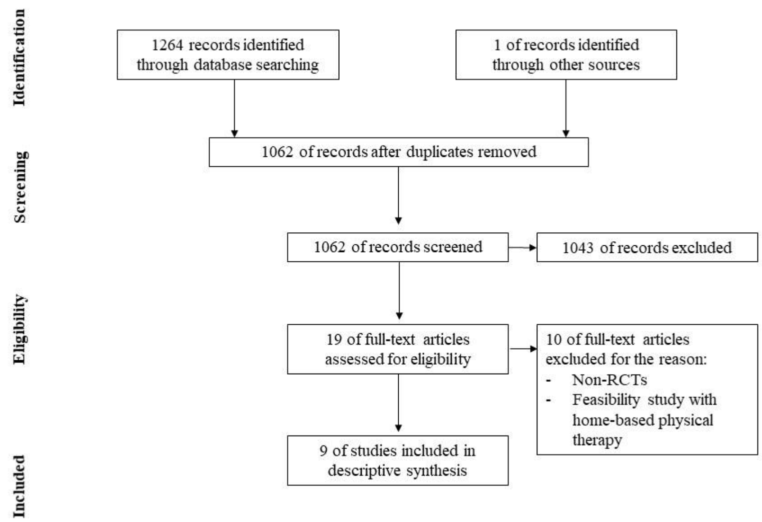

Figure 1. The flow of information through the different phases of the systematic review.

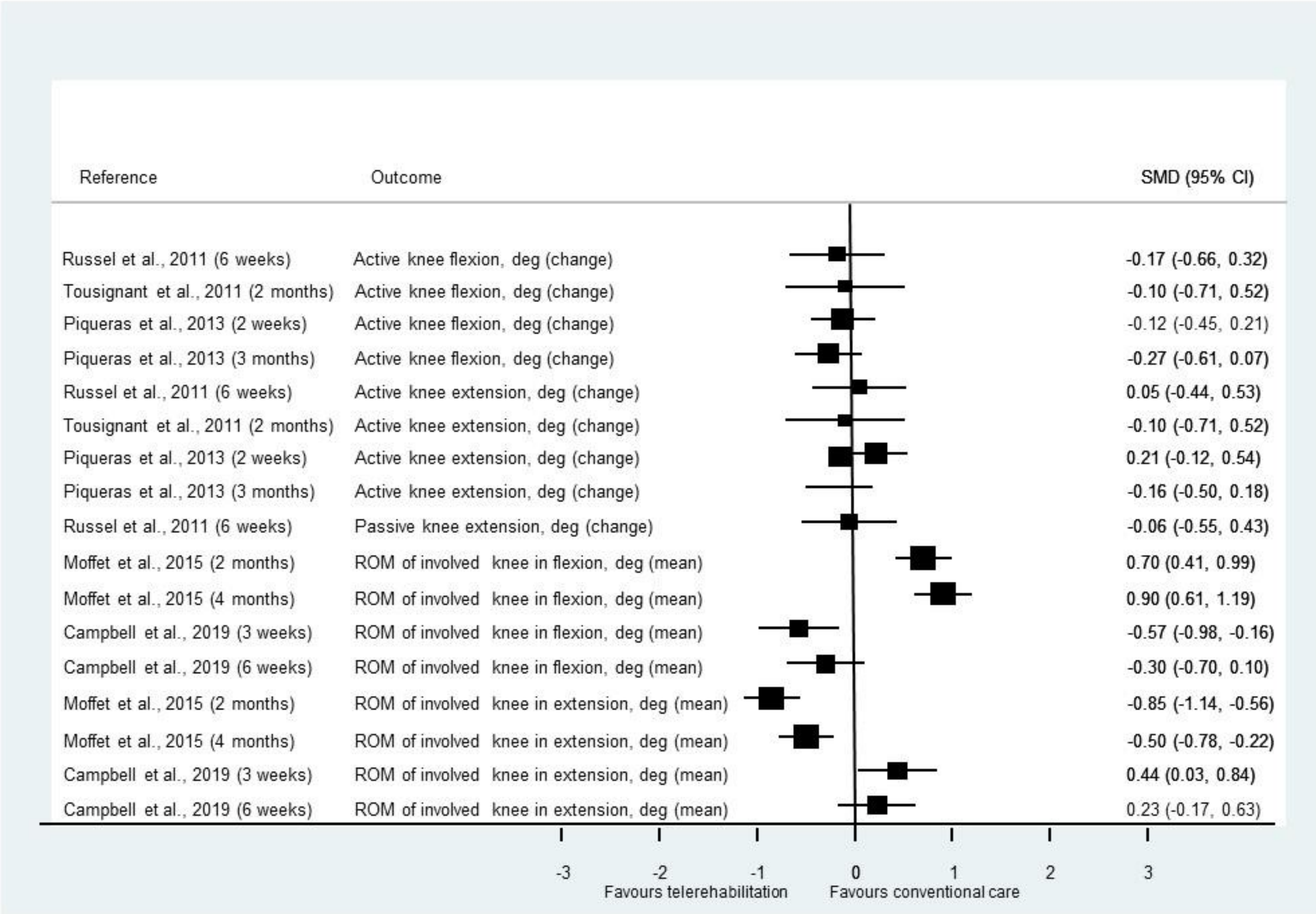

Figure 2. Telerehabilitation versus conventional in-person outpatient physical therapy rehabilitation for change in active and passive knee flexion and extension as well as range of motion (ROM).

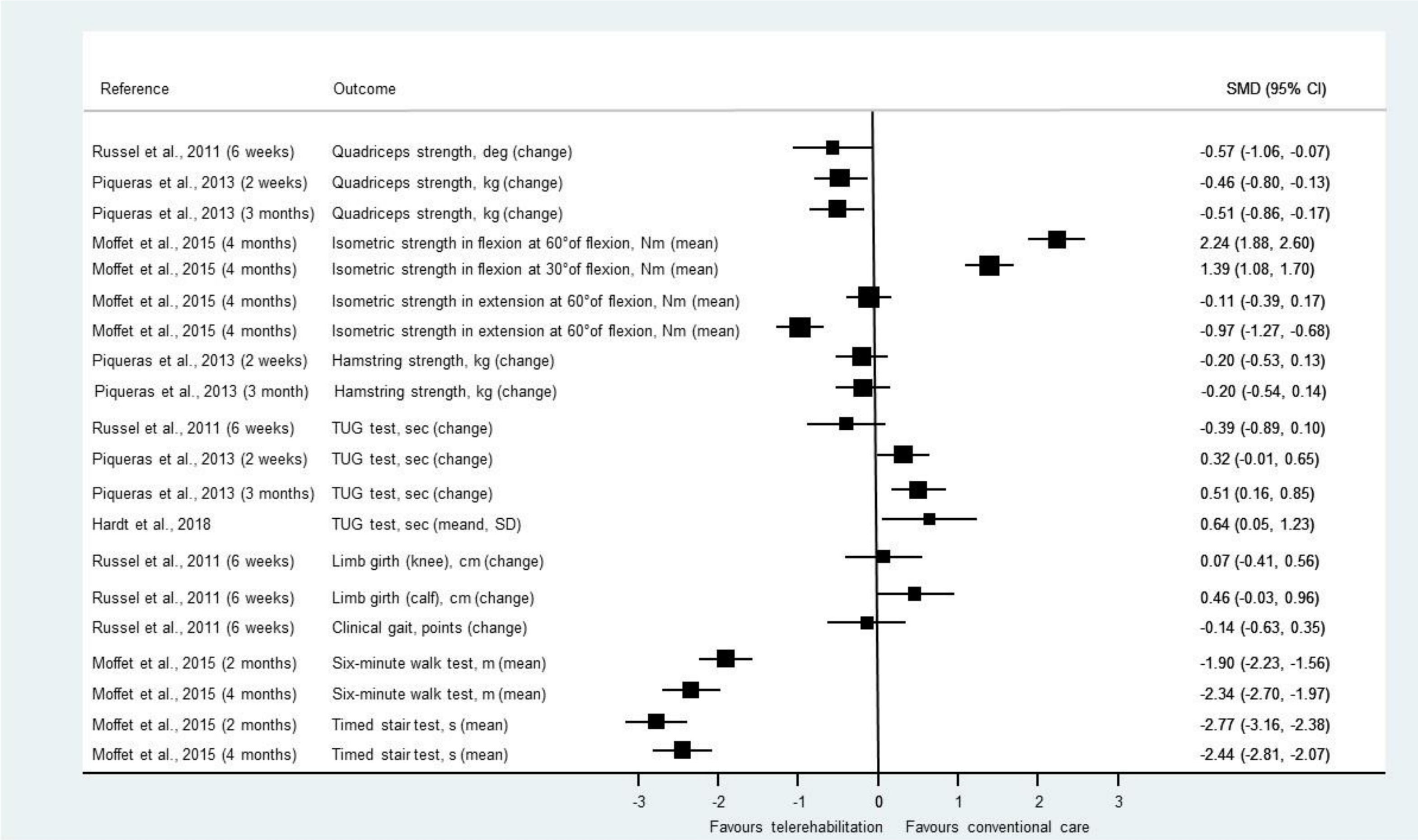

Figure 3. Telerehabilitation versus conventional in-person outpatient physical therapy rehabilitation for change in performance measures. TUG = Timed Up and Go test.

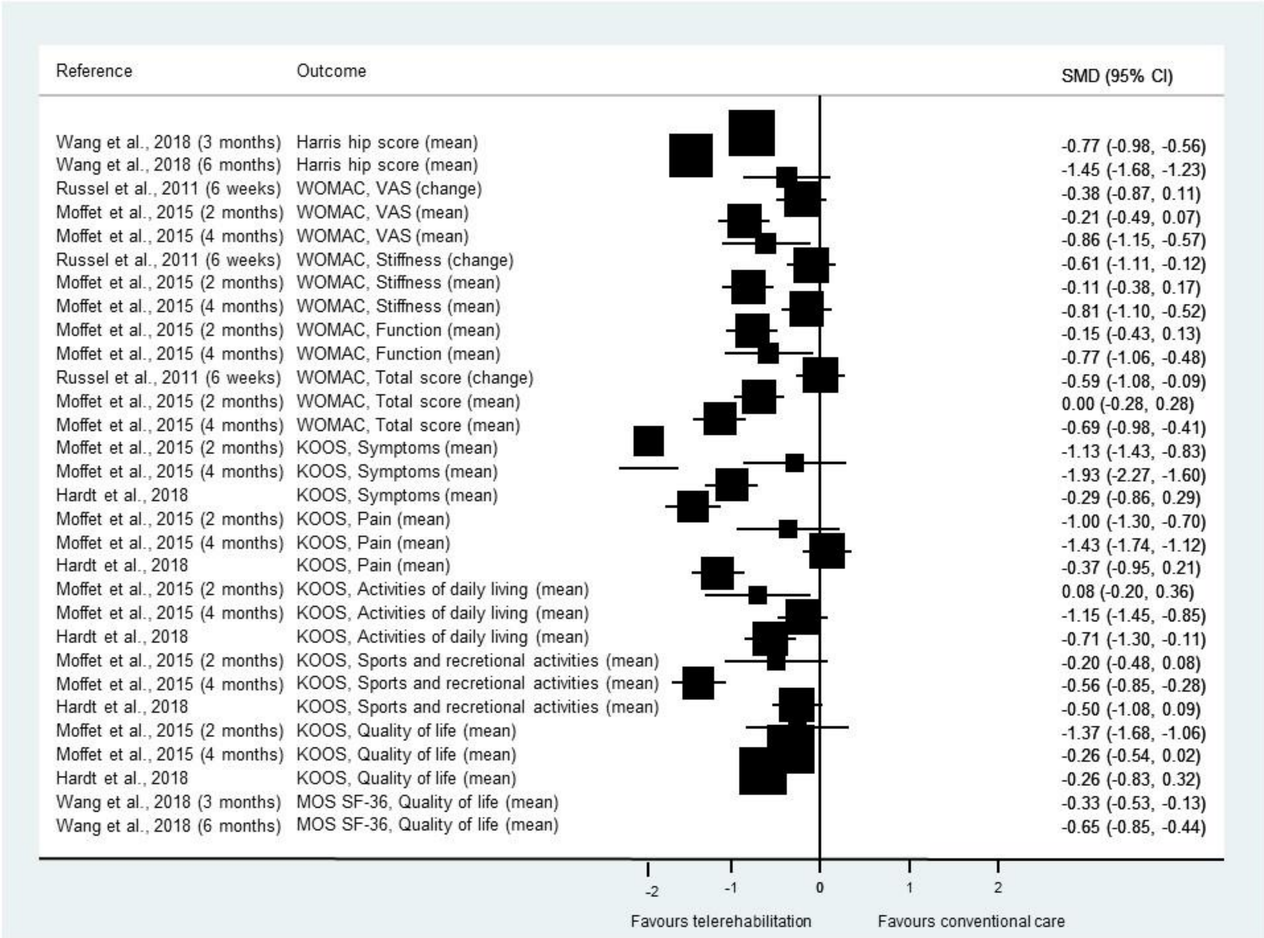

Figure 4. Telerehabilitation versus conventional in-person outpatient physical therapy rehabilitation for change in self-reported measures of physical functioning. WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index, KOOS = Knee Injury and Osteoarthritis Outcome Score, KOOS-PS = KOOS Physical Function Short Form.

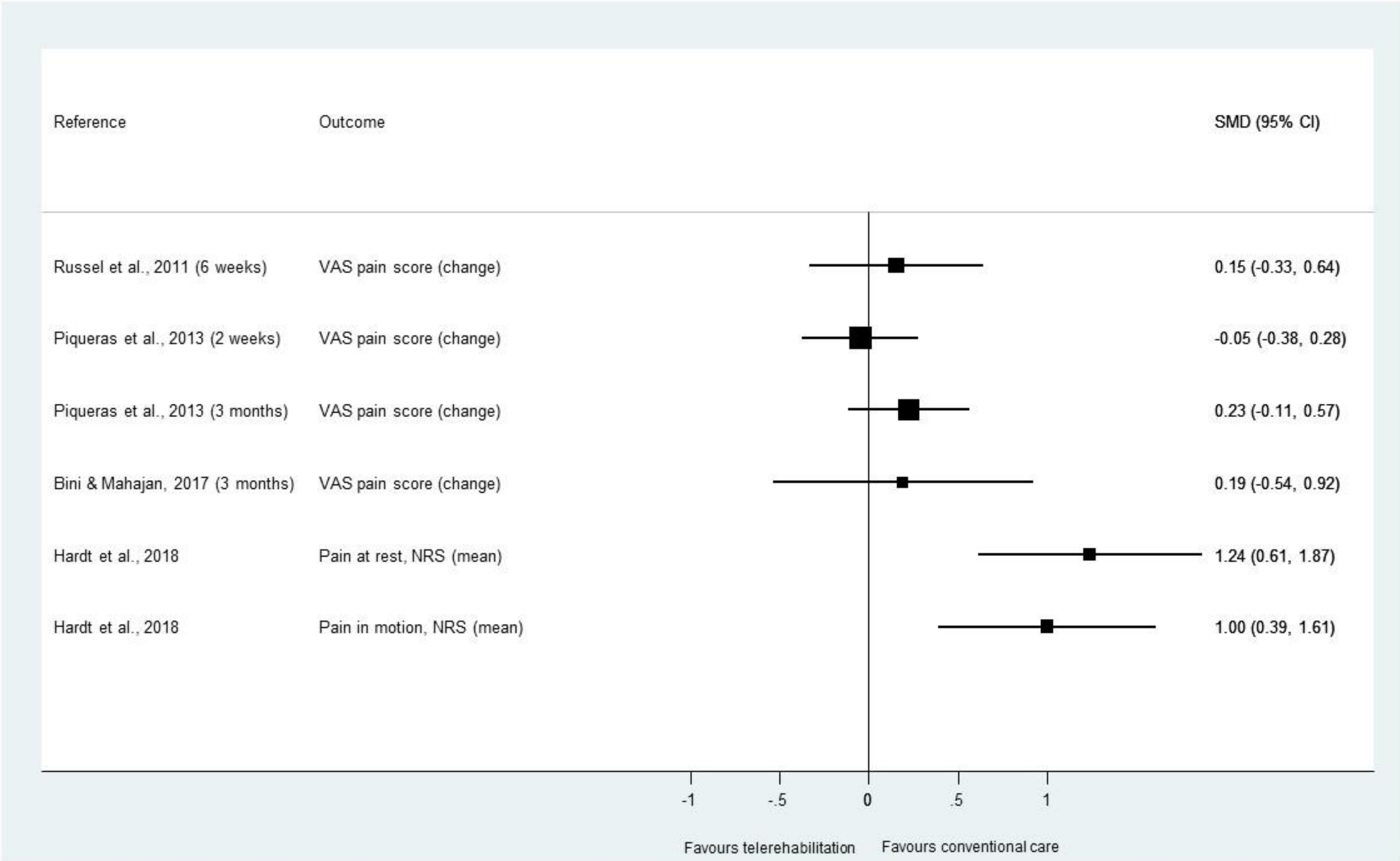

Figure 5. Telerehabilitation versus conventional in-person outpatient physical therapy rehabilitation for change in the intensity of pain.

Appendix 1. The search strategy involved the following search terms.

Database	Search terms
Ebsco Databases	(arthroplast* OR prosthe* OR endoprosthe*) AND joint* AND (tablet* OR "mobile app*" OR "m-health" OR mhealth OR "medical tehnolog*" OR telemedic* OR smartphone* OR "cell phone*" OR cellphone* OR "mobile phone*" OR "mobile device*" OR "mobile communicat*" OR "mobile technolog*" OR ehealth OR "e-health" OR "connected health" OR "information system*") *Limiters - Hidden NetLibrary Holdings* *Search modes - Boolean/Phrase*
Web of Science	TOPIC: (arthroplast* OR prosthe* OR endoprosthe*) *AND* TOPIC: (joint*) *AND* TOPIC: (tablet* OR "mobile app*" OR "m-health" OR mhealth OR "medical tehnolog*" OR telemedic* OR smartphone* OR "cell phone*" OR cellphone* OR "mobile phone*" OR "mobile device*" OR "mobile communicat*" OR "mobile technolog*" OR ehealth OR "e-health" OR "connected health" OR "information system*") *DocType=All document types; Language=All languages*