FinJeHeW Finnish Journal of eHealth and eWelfare

SCIENTIFIC PAPERS

VERTAISARVIOITU
KOLLEGIALT GRANSKAD
PEER-REVIEWED
www.tsv.fi/tunnus

Short-term effects of a digital patient journey solution on patient-reported outcomes and health care utilization in arthroplasty: a pragmatic randomized controlled trial

Miia Jansson[1,2], Hilkka Liedes[3], Anna-Leena Vuorinen[4], Marja Harjumaa[2,3], Heidi Similä[3], Jonna Koivisto[5], Ari-Pekka Puhto[6], Gillian Vesty[7], Hong-Gu He[8], Minna Pikkarainen[9,10]

[1] Research Unit of Health Sciences and Technology, University of Oulu, Oulu, Finland; [2] Oulu University Hospital, Oulu, Finland; [3] VTT Technical Research Centre of Finland Ltd, Oulu, Finland; [4] VTT Technical Research Centre of Finland Ltd, Tampere, Finland; [5] Faculty of Information Technology and Communication Sciences, Tampere University, Tampere, Finland; [6] OYS Centre for Musculoskeletal Surgery, Oulu University Hospital, Oulu, Finland; [7] School of Accounting, RMIT University, Melbourne, Australia; [8] Alice Lee Centre for Nursing Studies, Yong Loo Lin School of Medicine, National University of Singapore, Singapore; [9] Department for Rehabilitation Science and Health Technology & Department of Product Design, Oslomet, Oslo Metropolitan University, Norway; [10] Martti Ahtisaari Institute, University of Oulu, Finland

Miia Jansson, Adjunct Professor, PhD, RN, Research Unit of Health Sciences and Technology, University of Oulu, P.O. Box 5000, FI-90014 University of Oulu, FINLAND. Email: miia.jansson@oulu.fi

Abstract

Mobile health solutions for patient support have been proposed as promising and safe alternatives to usual care in adults undergoing primary total hip and knee arthroplasty. Studies of such applications, however, have produced conflicting results and only moderate- to low-quality evidence.

This study aims to evaluate the short-term effects of a digital patient journey solution on patient-reported outcomes and health care utilization in patients undergoing total hip and knee arthroplasty using a pragmatic randomized controlled trial design. Randomly allocated patients in the control arm (n = 35, 64 ± 9 years) received usual care, while patients in the intervention arm (n = 34, 62 ± 11 years) received the digital patient journey solution in addition to usual care.

The primary outcome was health-related quality of life as measured by the EuroQol EQ-5D-5L scale. Secondary outcomes included functional recovery, pain, self-efficacy, patient experience, adherence to fast-track protocol, and health care utilization. Participants were followed from a preoperative surgical visit until a postoperative follow-up visit at 6–12 weeks.

The health-related quality of life, functional recovery, pain, patient experience, adherence to the fast-track protocol, and health care utilization did not differ between the arms. During the study, however, the self-efficacy to use digital health services (p=0.027) increased in the intervention arm.

The use of the digital patient journey solution was not superior to usual care in terms of patient-reported outcomes and health care utilization. However, the solution improved the self-efficacy of patients to use digital health services, which may lead to greater demand for similar digital offerings as patient become more familiar with mobile health solutions.

Keywords: clinical trial, patient reported outcome measures, randomized controlled trial, telemedicine

Introduction

The prevalence of osteoarthritis (OA) is rapidly increasing due to an aging population and an increase in obesity [1]. Total hip arthroplasty (THA) and total knee arthroplasty (TKA) are common and cost-effective surgical operations to restore physical function, reduce joint related pain, and enhance health related quality of life (HRQoL) in patients with end-stage OA [2]. During the past decades, the number of THA and TKA surgeries has been increasing at a rapid rate [3,4].

Fast-track programs are generally successful and lead to good clinical outcomes, but the fast-tracking can be physically and psychologically challenging [5]. Even though patients are generally satisfied with the fast-track THA/TKA, they have diverse health information needs at different stages of the journey [6,7]. In addition, there is a need to foster patient adherence in fast-track programs to reduce modifiable risk factors, such as obesity, malnutrition, alcohol and tobacco use, which may lead to surgical complications [8].

Mobile health (mHealth) solutions have the potential to improve patient-provider communication and increase access to healthcare and reliable health information. In addition, they can increase HRQoL by facilitating independent living and maintaining social interaction [9], reduce pain by promoting self-management capabilities [9,10], improve functional recovery by enhancing physical activity [9-11], reduce health care utilization by improving patient adherence [10-13], decrease postoperative costs by requiring lesser postoperative physiotherapy and avoiding unnecessary healthcare visits [13,14], and reduce health care providers workloads by reducing the number of phone calls [10] in THA/TKA patients.

Previous studies, however, have produced conflicting results and only moderate- to low-quality evidence due to lack of experimental designs, validated instruments, and standardized content [15]. In addition, none of previous solutions have covered the entire THA/TKA journey from admission to discharge, and beyond, thus hampering information sharing and care coordination [16].

Material and methods

Aim

The primary aim of the study was to test the hypothesis that patients undergoing THA/TKA using the digital patient journey solution attain better HRQoL when compared to patients undergoing surgery receiving usual care without the solution. Further hypotheses assume that patients using the digital patient journey solution attain better functional recovery, experience less pain, attain better self-efficacy and patient experience, adhere better to the fast-track protocol, and utilize less healthcare resources than the control arm.

Design

A pragmatic randomized controlled trial (RCT) with two parallel arms was conducted to evaluate the short-term effects of a digital patient journey solution on patient-reported outcomes (PROs) and health care utilization in patients with THA/TKA [17].

Recruitment and randomization

The participants were screened and recruited during their preoperative surgical visit from a single university hospital in Finland by the research nurse. Once enrolled, the patients were randomized in a permuted blocks to either the intervention or control arm (allocation ratio of 1:1) by the research nurse, using sealed, opaque envelopes. The code break was kept secure by the research nurse.

Inclusion and exclusion criteria

Adult patients undergoing a primary, elective, and unilateral THA/TKA due to OA were eligible for inclusion. In addition, participants had to have a smart device; be able to communicate in Finnish; and be able to give written informed consent. Patients with cognitive or physical impairment inhibiting the use of mobile devices or patients unable to walk without walking aids were excluded.

Sample size and power

We aimed to detect a difference of 0.24 points (standard deviation = 0.27) in the EQ-5D-5L scores, which is considered a clinically important difference [18,19]. In total, 66 patients were required with a significance level α of 0.05, power of 90% and a dropout level of 15%.

Description of the interventions

During the study period, patient education was conducted in person by a multidisciplinary team using paper-based instructions and hands-on demonstrations at the preoperative patient clinic visit (usual care). Due to the COVID-19 pandemic, however, the delivery of a routine follow-up of THA/TKA patients changed from in person outpatient visits to phone calls.

The intervention arm received the digital patient journey solution in addition to usual care. With the digital patient journey solution, we refer to solution that provides monitoring features and advanced communication by encompassing the entire chain of care from the very first preoperative surgical visit until the postoperative follow-up visit.

The solution consisted of a native app for THA/TKA patients to support their patient journey (Fig. 1). The app was installed onto patients' personal smart device during the preoperative surgical visit, and they were informed about available technical phone support throughout the trial. A single face-to-face app training session was conducted by the research nurse. The app comprises the following features:

- Timeline with predefined tasks and clinical visits in the chronological order
- Information with multimedia content
- To-do list with manual confirmation, automatic reminders, and push notifications
- Self-monitoring for steps and pain
- Reporting forms and score cards
- Text chat and video calls

A clinician dashboard clinician consisted of design features and multimedia messaging that was developed to monitor patient status, adherence to prescheduled events and tasks, and intervene if patients require additional support (Fig. 1).

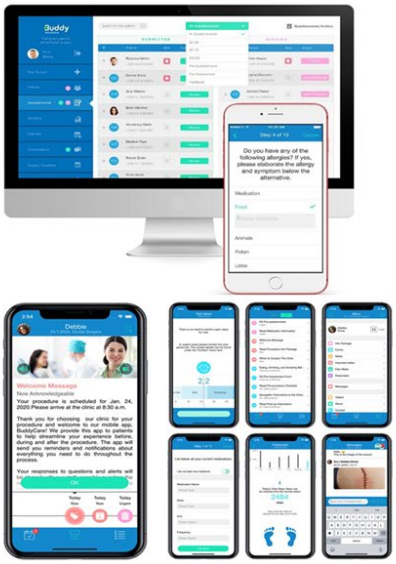

Figure 1. The patient counselling was delivered through the digital patient journey solution consisting of a native app for patients and a clinician dashboard for health care providers.

Data collection

PROs were collected between September 2019 and April 2021 using linguistically validated self-administered questionnaires and Finnish hip and knee arthroplasty register data. Baseline assessment was performed at the preoperative surgical visit. The follow-up assessment was performed 6 to 8 weeks post-discharge in patients with TKA and 8 to 12 weeks post-discharge in patients with THA. The same research nurse administered the questionnaires at all timepoints.

Variables and outcomes

Baseline characteristics

Baseline demographics were collected with questionnaires and clinical characteristics were collected from the electronic health records (EHR) during the preoperative surgical visit.

Primary outcome

The Finnish version of the EuroQol EQ-5D-5L scale was used to evaluate HRQoL [20]. The EQ-5D-5L consists of five domains related to mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. An index value of the EQ-5D-5L was calculated using the crosswalk value sets for UK and Denmark [21] because the Finnish value set or crosswalk set does not exist for the EQ-5D-5L. Patients' health today was rated on a Visual Analogue Scale (VAS).

Secondary outcomes

Functional recovery was measured with the Finnish version of the Western Ontario and McMaster Universities Osteoarthritis (WOMAC) index [22] and the Finnish version of the Oxford Hip Score (OHS) and the Oxford Knee Score (OKS) [23,24]. The WOMAC includes 24 items related to pain, stiffness, and function. Both OHS and OKS consist of 12 items related to pain and functional disability [25].

Intensity of pain was measured with the pain domain items of the EQ-5D-5L and WOMAC. In

addition, the total amount of pain medication (opioids), as retrieved from EHR, was estimated using morphine milligram equivalents per patient [26].

Healthcare technology self-efficacy was measured with an adapted version of the Healthcare Technology Self-Efficacy (HTSE) scale which evaluates patient's self-efficacy toward healthcare technology [27]. The HTSE includes 4 items related to motivational factors influencing intention to use health technologies.

Self-efficacy to perform preoperative and postoperative tasks was measured with self-reported survey items developed for the purposes of this study which evaluates patient's self-efficacy to perform preoperative and postoperative tasks with two items. Self-efficacy to perform postoperative rehabilitation activities, however, was measured with four items only from the intervention arm via the app at weeks 1, 3, and 5.

The patient experience regarding information sufficiency was measured using two unvalidated questions: 1) I received enough information regarding my care and 2) My family members/next of kin received enough information regarding my care.

Adherence to the fast-track protocol and health care utilization were extracted from EHR. Adherence to the fast-track protocol was measured by calculating the total number of patients who completed the pre-determined goals. By health care utilization, we mean nursing intensity, as measured by the Finnish version of the Oulu Patient Classification qualisan [28], the Perioperatiivinen Hoitoisuus qualisan [29], and use of health care services available, as measured by the length of stay (LOS), number of adverse events, rescheduling, number of health care visits, and number of phone calls.

Usage of the app during the study was measured by calculating usage metrics from the log files of the app.

Data analysis

All analyses used the intention-to-treat principle. Continuous and categorical variables were summarized using descriptive statistics. Missing values were not imputed except in the WOMAC index; individual missing values were imputed with the mean of a subject's non-missing values on the subscale. If ≥2 pain items, 2 stiffness items, or ≥4 function items were missing, imputation was not performed, and the subscale score was not calculated.

A linear mixed-effects model was used to assess differences over time between the study arms in EQ-5D-5L, WOMAC, OHS, OKS, and HTSE. The study arm, time, and their interaction were included as fixed effects and patients as random effects. Differences in continuous variables were assessed using Mann-Whitney U test. Differences in categorial variables were assessed using Fisher exact test or chi-squared test, as appropriate. Analyses were conducted using R (version 4.0.3), RStudio (version 1.2.5042), and package nlme (version 3.1-149) for linear mixed-effects models. Conclusions on statistical significance were based on the alpha level of 0.05. All performed statistical tests were two-sided.

Sensitivity analyses

Sensitivity analyses were performed to assess the possible impact of the ongoing COVID-19 pandemic on the results. We stratified the participants into two arms, i.e., those who had undergone surgery and completed the study before March 2020 and those who had done so after March 2020, and then analyzed the differences in the primary outcome respectively.

Ethical considerations

The study was approved by the local ethical committee (Ref no. 39/2019) in June 2019. The study was carried out on a voluntary basis. Written informed consent was obtained from participants before enrolment (Declaration of Helsinki, 2013).

Results

Subjects

Of the 707 patients screened for eligibility, 120 (17.0%) were found eligible, and a further 69 (9.8%) underwent randomization (Fig. 2). Of the 69 patients who started in the trial, 63 participants (91%) completed the study. The mean age of the patients was 63.2 years and 38 (55%) were women (Table 1). Both arms were statistically comparable for baseline characteristics.

Health related quality of life

There were no statistically significant time-group interactions between the control and intervention arms in the HRQoL measured using EQ-5D-5L index and VAS values (Table 2). The only statistically significant time-group interaction in the EQ-5D-5L subscales was the subscale of anxiety/depression (p=0.01).

Functional recovery, pain, self-efficacy, patient experience, adherence to the fast-track protocol, and health care utilization

There were no statistically significant time-group interactions in functional recovery (measured by WOMAC, OHS, and OKS) and intensity of pain (measured by subscales of EQ-5D-5L and WOMAC, Table 2, Table 3). There was also no statistically significant difference in the use of opioids between the control and intervention arms (Table 4).

There was a significant difference (p=0.027) in the level of self-efficacy to use digital health services. Self-efficacy to perform preoperative and postoperative tasks (Table 3) and postoperative rehabilitation activities did not differ between the study arms. The patient experience regarding information sufficiency did not differ between the study arms.

Adherence to the fast-track protocol and health care utilization (measured by nursing intensity, LOS, adverse events, rescheduling, health care visits, phone calls) did not differ between the study arms (Table 4). There was, however, a non-significant trend towards fever unplanned postoperative outpatient visits in the intervention arm.

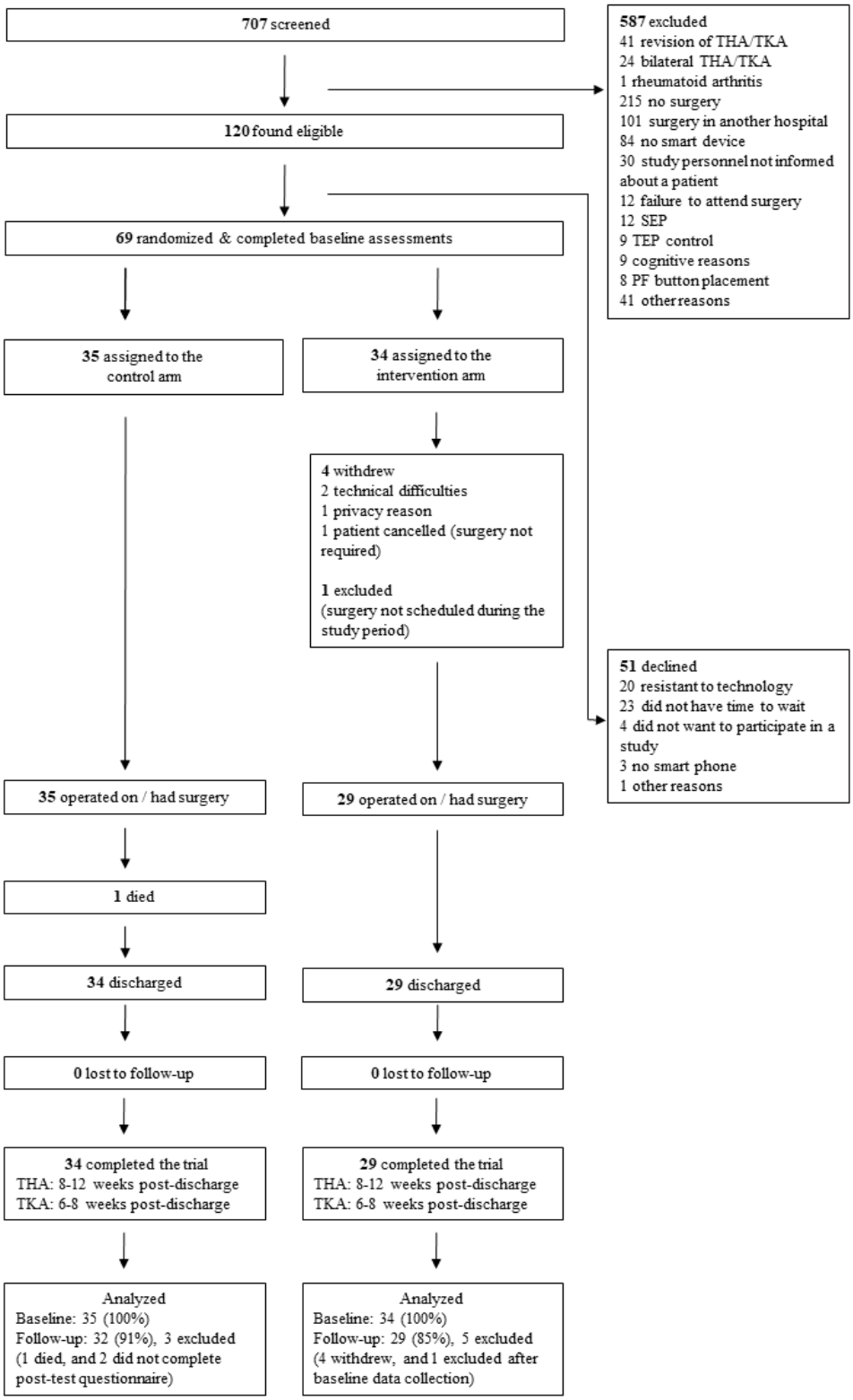

Figure 2. CONSORT Flowchart of the study.

Table 1. Baseline characteristics (n=69).

	Control arm (*n*=35)	**Intervention arm (*n*=34)**
Gender, *women*, n (%)	18 (51.4)	20 (58.8)
Age, *years*, mean (SD)	64 (8.5)	62 (11.2)
BMI, *kg/m²*, mean (SD)	30.9 (6.2)	29.1 (4.0)
Marital status, n (%)		
Single	2 (5.7)	5 (14.7)
Cohabitating	4 (11.4)	5 (14.7)
Married or in a registered relationship	25 (71.4)	21 (61.8)
Divorced or widowed	4 (11.4)	3 (8.8)
Education, n (%)		
Primary school or less	12 (34.3)	8 (23.5)
Upper secondary school	8 (22.9)	15 (44.1)
Bachelor's degree or equivalent	12 (34.3)	4 (11.8)
Master's degree or higher	3 (8.6)	7 (20.6)
Occupational status, n (%)		
Employed	8 (22.9)	13 (38.2)
Unemployed / on disability leave	3 (8.6)	1 (2.9)
Retired	24 (68.6)	18 (52.9)
Other	0 (0.0)	2 (5.9)
Type of surgery, n (%)		
Total hip arthroplasty	16 (45.7)	12 (35.3)
Total knee arthroplasty	19 (54.3)	22 (64.7)
Prior surgeries, n (%)		
Yes	34 (97.1)	31 (91.2)
No	1 (2.9)	3 (8.8)
Prior joint replacements, n (%)		
Yes	12 (34.3)	10 (29.4)
No	23 (65.7)	24 (70.6)
Use of walking aid, n (%)		
Yes	12 (34.3)	11 (32.4)
No	23 (65.7)	23 (67.6)

Table 2. Health related quality of life from baseline to follow-up.

	Control arm						Intervention arm						*P*
	Baseline			Follow-up			Baseline			Follow-up			time ×
	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	group
EQ-5D-5L													
Mobility	35	2.8	0.9	27	1.9	0.7	34	2.9	0.8	18	1.9	1.0	0.78
Self-care	35	1.6	0.7	27	1.3	0.5	34	1.3	0.7	18	1.3	0.6	0.34
Usual activities	35	2.3	1.1	27	1.8	0.8	34	2.0	0.9	18	1.9	0.9	0.42
Pain/discomfort	35	3.4	0.7	27	2.4	0.7	34	3.0	0.8	18	2.3	0.7	0.24
Anxiety/depression	35	1.6	0.7	27	1.2	0.4	34	1.2	0.5	18	1.4	0.5	0.01
Health today VAS	34	62.5	16.9	24	74.2	11.1	34	67.4	16.4	18	77.4	15.6	0.99
Index (DK)	34[a]	0.6	0.1	27	0.8	0.1	34	0.7	0.12	18	0.8	0.1	0.19
Index (UK)	34[a]	0.6	0.2	27	0.7	0.1	34	0.6	0.17	18	0.7	0.2	0.20

Abbreviations: VAS, Visual Analogue Scale; Index (DK), summary score derived using the crosswalk set for Denmark; Index (UK), summary score derived using the crosswalk value set for UK.

Interpretation: Mobility, self-care, usual activities, pain/discomfort, anxiety/depression are scored from 1 (no problems) to 5 (unable to/extreme problems) points. Health today VAS is scored from 0 (the worst imaginable health) to 100 (the best imaginable health). Index (DK) is scored from -0,624 to 1 and index (UK) is scored from -0.594 to 1. In both index values, negative values indicate health state that is worse than death, zero indicates death, and one indicates full health.

[a] one outlier removed (>4 standard deviations from the mean.

Table 3. Functional recovery and healthcare technology self-efficacy from baseline to follow-up.

	Control arm						Intervention arm						*P*
	Baseline			Follow-up			Baseline			Follow-up			time x group
	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	
Functional recovery													
WOMAC													
Pain	35	10.3	3.7	28	5.3	4.1	34	9.4	3.3	18	5.6	3.3	0.24
Stiffness	35	3.8	1.5	28	2.6	1.7	34	4.2	1.4	18	2.7	1.4	0.31
Physical function	35	34.3	13.2	28	18.4	12.7	34	29.2	12.1	18	15.3	11.6	0.65
Total	35	48.5	17.1	28	26.3	17.8	34	42.8	15.5	18	23.7	15.3	0.60
Oxford Knee Score	18	23.6	7.3	15	35.1	7.9	18	24.6	7.1	17	37.0	5.4	0.80
Oxford Hip Score	14	19.6	9.2	13	41.8	6.7	10	17.9	8.7	10	39.3	6.8	0.88
Healthcare Technology Self-Efficacy													
I think it is easy to use digital health services	35	4.4	0.7	27	3.8	1.2	34	4.2	1.1	21	4.2	0.9	0.132
I find the use of digital health services unpleasant	35	1.6	0.9	27	2.1	1.4	34	1.9	1.2	21	1.8	1.2	0.127
I am confident in my ability to use digital health services	35	4.6	0.5	27	4.0	1.1	34	4.2	1.0	21	4.3	1.2	0.027
I can use digital health services without much effort	35	4.5	0.7	27	4.0	1.3	34	4.4	0.7	21	4.5	0.8	0.095

Abbreviations: WOMAC, Western Ontario and McMaster Universities Osteoarthritis index; SD, standard deviation

Interpretation: WOMAC: scale for pain is 0-20 points, stiffness 0-8 points, function 0-68 points, and total score 0-96, higher values indicating poorer condition. Oxford Hip Score and Oxford Knee Score: scale ranges from 0 to 48, with higher values indicating better condition. Healthcare Technology Self-Efficacy: Likert scale from 1 to 5 (i.e., from completely disagree to completely agree), with higher values indicating higher self-efficacy.

Table 4. Use of opioids, adherence to the fast-track protocol and health care utilization.

	N	Control arm	N	Intervention arm	*P* value
Pain					
Use of opioids					
MME, median (IQR)	35	141 (91; 177)	29	123 (84; 197)	0.530
Fentanyl IV (microg), median (IQR)	26	80 (25; 179)	24	48 (20; 71)	0.096
Adherence to the fast-track protocol, n (%)					
Mobilized on Day 0 (yes)	35	24 (68.6)	29	23 (79.3)	0.402
Mobilized for elbows on Day 1 (yes)	35	19 (54.3)	28	13 (46.4)	0.616
Discharged on Day 2–3 (yes)	35	27 (77.1)	29	25 (86.2)	0.522
Health care utilization					
Nursing intensity					
OPCq on Day 0–1[1]	34	4 (4; 4)	29	4 (4; 4)	Na
OPCq on Day 1–2	34	3 (3; 4)	29	3 (3; 3)	0.437
OPCq on Day 2–3	12	3 (3; 3)	12	3 (3; 3)	1.000
Perihoiq (points) during operation	19	17 (15; 19)	18	16 (15; 17)	0.262
Perihoiq (class) during operation	19	4 (3; 4)	18	4 (3; 4)	0.731
Perihoiq (points) post operation	19	15 (14; 17)	15	13 (13; 16)	0.100
Perihoiq (class) post operation	19	3 (3; 4)	15	3 (3; 4)	0.252
Length of stay (days), median IQR	35	2 (2; 3)	29	2 (2; 3)	0.951
Adverse events, n (%)	32	4 (12.5)	27	0 (0.0)	0.118
Rescheduling, n (%)					
Surgery (yes)	35	6 (17.1)	29	9 (31.0)	0.242
Follow-up visit (yes)	34	8 (23.5)	29	2 (6.9)	0.092
Health care visits, n (%)					
Preoperative outpatient visits	35		29		0.304
1 visit		25 (71.4)		17 (58.6)	
2–9 visits		10 (28.6)		12 (41.4)	
Postoperative outpatient visits (planned)	31	5 (16.1)	27	2 (7.4)	0.432
Postoperative outpatient visits (unplanned)	31	8 (25.8)	28	3 (10.7)	0.187
Calls prior surgery					0.798
0 calls	35	23 (65.7)	29	18 (62.1)	
1–4 calls		12 (34.3)		11 (37.9)	
Calls postsurgery	31		27		1.000
0 calls		19 (61.3)		16 (59.3)	
1–5 calls		12 (38.7)		11 (40.7)	

Abbreviations: MME, morphine milligram equivalent; IQR, interquartile range; OPCq, Oulu Patient Classification qualisan; PERI-HOIq, Perioperatiivinen Hoitoisuus qualisan.[1] All had value of four, the P value could not be calculated.

Sensitivity analyses

The results from the COVID-19 sensitivity analyses, in which the patients were stratified into the arms of people completing the study before and during the COVID-19 pandemic, respectively, were concordant with the unstratified results.

Usage of the app

The median time spent for registration of the app was 2.1 minutes (interquartile range 1.6–3.9). In addition, the time spent on initial training took on average 21.1 (standard deviation 4.9) minutes. During the study, median app usage time was 194 minutes, the median number of app usage days was 44, and 18 patients (58.1%) sent messages. The app was used both before and postsurgery. The app crashed four times for one patient and once for another patient. Obtained errors (n=5) were related to the execution or timing of notifications and reminders. The preoperative queries were related to laboratory tests (no:7), preoperative preparation (no:4), pain management (no:1), care planning (no:19), and the app itself (no:6). The postoperative queries were related to laboratory tests (no:1), pain management (no:9), medication (no:7), wound (no:1), discharge (no:2), follow-up visit (no:5), and recovery (no:3). In addition, one subject sent three images related to signs and symptoms of an infection preoperatively.

Discussion

This is the first pragmatic RCT with repeated measurements to evaluate the effects of a digital patient journey solution on PROs and health care utilization in patients with THA/TKA. Unfortunately, the experiment failed to confirm our hypothesis that the use of digital patient journey solution improves PROs and reduces health care utilization in total joint arthroplasty.

In line with previous studies using mHealth applications [13-14], the HRQoL did not differed between the study arms due to lack of significant between-groups difference in the functional recovery and pain, which are the two main dimensions of HRQoL [23]. According to Christiansen et al. [8], mHealth solutions can increase HRQoL by facilitating independent living and maintaining social interaction. The factors associated with the superiority of digital solutions on HRQoL, however, are unknown.

According to our findings, the EQ-5D-5L sub-scale of anxiety/depression differed slightly between the study arms. However, it remains inconclusive whether this difference was due to the difference at baseline or app usage. In addition, the level of anxiety was low in our population. In the previous literature, anxiety and depression have had an adverse impact on health care utilization, intensity of pain, and HRQoL. Standardized preventive solutions are, however, lacking despite a number of different mental health apps have decreased the levels of anxiety [30].

Previous experimental [9,10] and quasi-experimental [11] studies have found significant between-groups difference in the functional recovery and intensity of pain by using mHealth solutions with and without tailored exercise programs (daily exercises, reminders, and real-time tracking) which have increased physical activity and improved functional recovery in THA/TKA patients [9-12], whereas our solution focused solely on untailored multimedia content. The factors associated with the superiority of digital solutions vs. conventional care, however, are not clear.

During the study period, the level of self-efficacy to use digital health services increased slightly in the intervention arm. However, the self-efficacy to perform preoperative and postoperative tasks and postoperative rehabilitation activities did not differ

between the study arms. In the previous 12-week single-arm intervention study, self-efficacy for managing symptoms and daily activities improved significantly by using digital behavioural health intervention in patients undergoing TKA [31]. However, rigorous assessment will be needed to confirm these findings in the future.

According to Abdeen et al. [3], mHealth solutions can increase compliance with a preoperative protocol and thus, reduce the LOS by using timed reminders. During the study, however, adherence to the fast-track protocol did not differ between the study arms, which may be related to highly standardized practices and optimized pathway due to existing Lean approach. In general, the use of digital solutions has decreased postoperative costs by avoiding unnecessary healthcare visits in patients with THA/TKA [10,13-14].

In line with previous literature [14,32], the use of the digitalized solutions did not reduce the number of phone calls, which may be due to lack of comfort and familiarity with technology. In addition, patients may prefer calling in certain circumstances, e.g., they are accustomed to take care of health care issues via phone, they might have several questions, they need to reschedule the surgery due to flu symptoms during the COVID-19 pandemic.

Strengths and limitations of the study

Contrary to previous moderate- to low-quality evidence, this is the first pragmatic RCT using language-appropriate and culturally validated questionnaires to evaluate the multiple effects of digital patient journey solution in patients undergoing THA/TKA. Contrary to previous studies, the whole THA/TKA journey from admission to discharge and beyond was covered to support the patient journey from a multidisciplinary perspective.

A number of limitations in the current study are, however, acknowledged. First, the intervention was not pilot-tested because the feasibility and usability of the digital patient journey solution has been tested in other surgical specialties and countries. Second, results may have limited applicability to settings outside of university hospitals, other countries, or to patients who are younger or have not previously undergone surgery. Third, blinding of the study arms was unfeasible. The arm assignment was, however, blinded until the baseline assessments were completed. Fourth, the response rates for the follow-up questionnaires were lower in the intervention arm, which might decrease the power of the study. Despite the intervention arm receiving push notifications about the assessment, the dedicated response time ended prematurely, leading to a lack of responses. Fifth, during the recruitment, 20 patients declined due to their resistance to technology adoption, while two participants were lost due to technical issues with the downloading the app. The app usage statistics studied here, however, do not allow a closer examination of the usage behavior of the patients.

Recommendations for further research

Tailored exercise programs with real-time tracking should be designed to improve physical activity and thus, functional recovery in patients with THA/TKA. The tailored exercise programs could be integrated as part of the digital patient journey solutions covering the whole THA/TKA journey from admission to discharge and beyond. Future research is needed to understand the factors associated with the superiority of digital solutions to develop theory-based interventions. Digital patient journey solutions can be used to improve patient-provider communication, but the effects should be evaluated as an element of digital care rather than supplementing conventional in person follow-up. In addition, the

impact of digital solutions should be evaluated at by patients (e.g., patient-reported health status, patient experience), healthcare providers (e.g., changes in processes and system performance/health), and health organizations (e.g., reduction of cost, implementation costs, error rates) level using standardized outcomes, measurement tools, and time points in patients with THA/TKA.

Conclusions

The use of the digital patient journey solution was not superior to usual care in terms of patient-reported outcomes and health care utilization. However, the solution improved the self-efficacy of patients to use digital health services, which may lead to greater demand for similar digital offerings as patient become more familiar with mobile health solutions. This improved self-efficacy also confirms the suitability of the digital patient journey solution and opens up the possibility for more nuanced examination in future research.

Author contributions

Miia Jansson: methodology (equal); writing – original draft (lead); visualization (lead). Hilkka Liedes: analysis (lead); writing – review and editing (equal). Anna-Leena Vuorinen: methodology (equal); analysis (lead); writing – review and editing (equal). Marja Harjumaa: methodology (equal); writing – review and editing (equal). Heidi Similä: methodology (equal); writing – review and editing (equal). Jonna Koivisto: methodology (equal); writing – review and editing (equal). Ari-Pekka Puhto: methodology (equal); writing – review and editing (equal). Gillian Vesty: methodology (equal); writing – review and editing (equal). Hong-Gu He: writing – review and editing (equal). Minna Pikkarainen: funding acquisition (lead); project administration (lead); writing – review and editing (equal).

Funding

Business Finland

Conflict of interest statement

All authors declare no conflicts of interest.

Acknowledgments

This study was financially supported by Business Finland, for which we are sincerely grateful. We are also grateful to the Oulu University Hospital patients who agreed to participate in this research project.

References

[1] Institute for Health Metrics and Evaluation. Global Burden of Disease Data 2019. University of Washington, Seattle WA; 2020 [cited 2022 Nov 14]. Available from: https://www.healthdata.org/research-analysis/gbd

[2] Wilson RA, Gwynne-Jones DP, Sullivan TA, Abbott JH. Total Hip and Knee Arthroplasties Are Highly Cost-Effective Procedures: The Importance of Duration of Follow-Up. J Arthroplasty. 2021 Jun;36(6):1864-1872.e10. https://doi.org/10.1016/j.arth.2021.01.038

[3] Williams SN, Wolford ML, Bercovitz A. Hospitalization for Total Knee Replacement Among Inpatients Aged 45 and Over: United States, 2000-2010. NCHS Data Brief. 2015 Aug;(210):1-8.

[4] Wolford ML, Palso K, Bercovitz A. Hospitalization for total hip replacement among inpatients aged 45 and over: United States, 2000-2010. NCHS Data Brief. 2015 Feb;(186):1-8.

[5] Jansson MM, Harjumaa M, Puhto AP, Pikkarainen M. Healthcare professionals' proposed eHealth needs in elective primary fast-track total hip and knee arthroplasty journey: A qualitative interview study. J Clin Nurs. 2019 Dec;28(23-24):4434-4446. https://doi.org/10.1111/jocn.15028

[6] Jansson MM, Harjumaa M, Puhto AP, Pikkarainen M. Patients' satisfaction and experiences during elective primary fast-track total hip and knee arthroplasty journey: A qualitative study. J Clin Nurs. 2020 Feb;29(3-4):567-582. https://doi.org/10.1111/jocn.15121

[7] Johns WL, Layon D, Golladay GJ, Kates SL, Scott M, Patel NK. Preoperative Risk Factor Screening Protocols in Total Joint Arthroplasty: A Systematic Review. J Arthroplasty. 2020 Nov;35(11):3353-3363. https://doi.org/10.1016/j.arth.2020.05.074

[8] Christiansen L, Lindberg C, Berglund SJ, Anderberg P, Skär L. Using Mobile Health and the Impact on Health-Related Quality of Life: Perceptions of Older Adults with Cognitive Impairment. Int J Environ Res Public Health. 2020 Apr 13;17(8):2650. https://doi.org/10.3390/ijerph17082650

[9] Gohir SA, Eek F, Kelly A, Abhishek A, Valdes AM. Effectiveness of Internet-Based Exercises Aimed at Treating Knee Osteoarthritis: The iBEAT-OA Randomized Clinical Trial. JAMA Netw Open. 2021 Feb 1;4(2):e210012. https://doi.org/10.1001/jamanetworkopen.2021.0012

[10] Campbell KJ, Louie PK, Bohl DD, Edmiston T, Mikhail C, et al. A Novel, Automated Text-Messaging System Is Effective in Patients Undergoing Total Joint Arthroplasty. J Bone Joint Surg Am. 2019 Jan 16;101(2):145-151. https://doi.org/10.2106/JBJS.17.01505

[11] van Dijk-Huisman HC, Weemaes ATR, Boymans TAEJ, Lenssen AF, de Bie RA. Smartphone App with an Accelerometer Enhances Patients' Physical Activity Following Elective Orthopedic Surgery: A Pilot Study. Sensors (Basel). 2020 Aug 2;20(15):4317. https://doi.org/10.3390/s20154317

[12] Abdeen A, Monárrez R, Drew JM, Kennedy KF. Use of a Smart-Phone Mobile Application is Associated with Improved Compliance and Reduced Length of Stay in Patients Undergoing Primary Total Joint Arthroplasty of the Hip and Knee. J Arthroplasty. 2022 Aug;37(8):1534-1540. https://doi.org/10.1016/j.arth.2022.03.068

[13] Colomina J, Drudis R, Torra M, Pallisó F, Massip M, Vargiu E, Nadal N, Fuentes A, Ortega Bravo M, Miralles F, Barbé F, Torres G, de Batlle J; CONNECARE-Lleida Group. Implementing mHealth-Enabled Integrated Care for Complex Chronic Patients with Osteoarthritis Undergoing Primary Hip or Knee Arthroplasty: Prospective, Two-Arm, Parallel Trial. J Med Internet Res. 2021 Sep 2;23(9):e28320. https://doi.org/10.2196/28320

[14] Crawford DA, Duwelius PJ, Sneller MA, Morris MJ, Hurst JM, Berend KR, Lombardi AV. 2021 Mark Coventry Award: Use of a smartphone-based care platform after primary partial and total knee arthroplasty: a prospective randomized controlled trial. Bone Joint J. 2021 Jun;103-B(6 Supple A):3-12. https://doi.org/10.1302/0301-620X.103B6.BJJ-2020-2352.R1

[15] Jansson MM, Hyvämäki P, Pikkarainen M. Computer- and telephone-delivered interventions on patient outcome and resource utilization in patients with orthopedic conditions: A systematic review and narrative synthesis. Orthop Nurs. 2020 Sep/Oct;39(5):340-352. https://doi.org/10.1097/NOR.0000000000000699

[16] Teisberg E, Wallace S, O'Hara S. Defining and Implementing Value-Based Health Care: A Strategic

Framework. Acad Med. 2020 May;95(5):682-685. https://doi.org/10.1097/ACM.0000000000003122

[17] Jansson M, Vuorinen AL, Harjumaa M, Similä H, Koivisto J, Puhto AP, Vesty G, Pikkarainen M. The digital patient journey solution for patients undergoing elective hip and knee arthoplasty due to primary osteoarthritis: Protocol for a pragmatic randomized controlled trial. J Adv Nurs. 2020 Jun;76(6):1436-1448. https://doi.org/10.1111/jan.14343

[18] Bilbao A, García-Pérez L, Arenaza JC, García I, Ariza-Cardiel G, Trujillo-Martín E, Forjaz MJ, Martín-Fernández J. Psychometric properties of the EQ-5D-5L in patients with hip or knee osteoarthritis: reliability, validity and responsiveness. Qual Life Res. 2018 Nov;27(11):2897-2908. https://doi.org/10.1007/s11136-018-1929-x

[19] Conner-Spady BL, Marshall DA, Bohm E, Dunbar MJ, Noseworthy TW. Comparing the validity and responsiveness of the EQ-5D-5L to the Oxford hip and knee scores and SF-12 in osteoarthritis patients 1 year following total joint replacement. Qual Life Res. 2018 May;27(5):1311-1322. https://doi.org/10.1007/s11136-018-1808-5

[20] Herdman M, Gudex C, Lloyd A, Janssen M, Kind P, Parkin D, Bonsel G, Badia X. Development and preliminary testing of the new five-level version of EQ-5D (EQ-5D-5L). Qual Life Res. 2011 Dec;20(10):1727-36. https://doi.org/10.1007/s11136-011-9903-x

[21] van Hout B, Janssen MF, Feng YS, Kohlmann T, Busschbach J, Golicki D, Lloyd A, Scalone L, Kind P, Pickard AS. Interim scoring for the EQ-5D-5L: mapping the EQ-5D-5L to EQ-5D-3L value sets. Value Health. 2012 Jul-Aug;15(5):708-15. https://doi.org/10.1016/j.jval.2012.02.008

[22] Bellamy N, Wilson C, Hendrikz J, Whitehouse SL, Patel B, Dennison S, Davis T; EDC Study Group. Osteoarthritis Index delivered by mobile phone (m-WOMAC) is valid, reliable, and responsive. J Clin Epidemiol. 2011 Feb;64(2):182-90. https://doi.org/10.1016/j.jclinepi.2010.03.013

[23] Dawson J, Fitzpatrick R, Carr A, Murray D. Questionnaire on the perceptions of patients about total hip replacement. J Bone Joint Surg Br. 1996 Mar;78(2):185-90. https://doi.org/10.1302/0301-620X.78B2.0780185

[24] Dawson J, Fitzpatrick R, Murray D, Carr A. Questionnaire on the perceptions of patients about total knee replacement. J Bone Joint Surg Br. 1998 Jan;80(1):63-9. https://doi.org/10.1302/0301-620X.80B1.7859

[25] Murray DW, Fitzpatrick R, Rogers K, Pandit H, Beard DJ, Carr AJ, Dawson J. The use of the Oxford hip and knee scores. J Bone Joint Surg Br. 2007 Aug;89(8):1010-4. https://doi.org/10.1302/0301-620X.89B8.19424

[26] Von Korff M, Saunders K, Thomas Ray G, Boudreau D, Campbell C, Merrill J, Sullivan MD, Rutter CM, Silverberg MJ, Banta-Green C, Weisner C. De facto long-term opioid therapy for noncancer pain. Clin J Pain. 2008 Jul-Aug;24(6):521-7. https://doi.org/10.1097/AJP.0b013e318169d03b

[27] Asimakopoulos S, Asimakopoulos G, Spillers F. Motivation and user engagement in fitness tracking: Heuristics for mobile Healthcare wearables. Informatics 2017;4(1):5. https://doi.org/10.3390/informatics4010005

[28] Fagerström L, Lønning K, Andersen MH. The RAFAELA system: a workforce planning tool for nurse staffing and human resource management. Nurs Manag (Harrow). 2014 May;21(2):30-6. https://doi.org/10.7748/nm2014.04.21.2.30.e1199

[29] Junttila JK, Koivu A, Fagerström L, Haatainen K, Nykänen P. Hospital mortality and optimality of

nursing workload: A study on the predictive validity of the RAFAELA Nursing Intensity and Staffing system. Int J Nurs Stud. 2016 Aug;60:46-53. https://doi.org/10.1016/j.ijnurstu.2016.03.008

[30] Lecomte T, Potvin S, Corbière M, Guay S, Samson C, Cloutier B, Francoeur A, Pennou A, Khazaal Y. Mobile Apps for Mental Health Issues: Meta-Review of Meta-Analyses. JMIR Mhealth Uhealth. 2020 May 29;8(5):e17458. https://doi.org/10.2196/17458

[31] Visperas AT, Greene KA, Krebs VE, Klika AK, Piuzzi NS, Higuera-Rueda CA. A Web-Based Interactive Patient-Provider Software Platform Does Not Increase Patient Satisfaction or Decrease Hospital Resource Utilization in Total Knee and Hip Arthroplasty Patients in a Single Large Hospital System. J Arthroplasty. 2021 Jul;36(7):2290-2296.e1. https://doi.org/10.1016/j.arth.2021.01.037

[32] Godziuk K, Prado CM, Quintanilha M, Forhan M. Acceptability and preliminary effectiveness of a single-arm 12-week digital behavioral health intervention in patients with knee osteoarthritis. BMC Musculoskelet Disord. 2023 Feb 17;24(1):129. https://doi.org/10.1186/s12891-023-06238-8