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Research Article

Reference Values for Pain and Range of Motion and Exercise Profiles after Total-Knee Arthroplasty: Results from a Randomized Controlled Trial

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Abstract

Objectives: To establish reference values for pain and knee range of motion during the first 8-weeks following a primary TKA and to describe the exercises that were more frequently prescribed by physiotherapists using an intensive functional approach.

Methods: All adults (n=197) from the TelAge randomised controlled-trial on the efficacy of in-home telerehabilitation after a primary TKA were included in this descriptive study. They received 16 physiotherapy treatments during an 8 week-intervention period following hospital discharge. The intervention was delivered through an in-home telerehabilitation approach for the experimental group and with home visits (usual face-to-face approach) for the control group. At each treatment, knee pain intensity, knee range of motion and exercises prescribed by the physiotherapist were documented and analysed.

Results: The 50th, 85th and 95th percentiles for evolution of pain and knee range of motion were described for the whole sample as no significant difference between groups was found. A descriptive analysis of the exercise profiles demonstrates similar proportions in both groups of patients practicing the different categories of exercises, except stair task training.

Conclusion: Reference values for the evolution of two commonly used outcomes, knee pain and range of motion, as well as data on timing and type of exercises prescribed in the two first months after TKA are important information to guide physiotherapists in the identification of patients with a delayed recovery and for exercise prescription in the early stage of recovery.

Keywords: Knee Arthroplasty; Telerehabilitation; Exercise; Physical Therapy; Reference Values

Abbreviations

CI: Confidence Interval; Deg: Degree; ICC: Intraclass Correlation Coefficient; PT: Physical Therapy; ROM: Range of motion; SD: Standard Deviation; STD: Standard Home-visits Group; TELE: Telerehabilitation Group; TKA: Total Knee Arthroplasty; T1 to T16: Treatment session 1 to Treatment session 16

Introduction

In Canada, the number of Total Knee Arthroplasty (TKA) surgeries for the treatment of knee osteoarthritis has been increasing steadily over the last decade [1]. This large volume of surgeries may be partially explained by aging of the Canadian population, as prevalence for knee osteoarthritis increases with age [2,3]. Indeed, about 40 % of people aged over 65 years old experience pain and reduced mobility from this condition [4]. It also results from governing bodies appointing TKA as a priority surgery to reduce lengthy waitlists [5]; leading to over 67,000 TKAs performed in Canada for the years 2016 and 2017 only [6]. Rehabilitation services are essential for early recovery after TKA [7]. As post-operative hospital length-of-stay shortens [8], rehabilitation following TKA is mostly undertaken by community-based physiotherapists after discharge. Although there are no absolute clinical guidelines for Physiotherapy (PT) after TKA, the main treatment goals aim at improving knee Range Of Motion (ROM), strength of knee flexors and extensors, gait pattern and overall physical function [9,10].

Many studies agree that a successful PT intervention after TKA addresses post-operative quadriceps weakness and atrophy [11,12]. Improved clinical outcomes have been demonstrated with intensive functional exercise programs, in comparison to lower intensity regimens [13,14]. Nonetheless, functional deficits can persist despite surgery and rehabilitation: many patients demonstrate persisting knee extensor weakness two years after surgery [15]. The capacity to perform functional movements such as kneeling or squatting can remain restricted after TKA when compared to age-matched controls [16]. Moreover, significant functional deficits in gait can be observed as early as 2-months post-TKA [17]. With the high volume of TKA surgeries, delivering the most efficient PT interventions to achieve optimal functional level and meet expectations of patients is essential. Unfortunately, there is little information regarding the evolution of widely used clinical outcomes such as pain and knee ROM, during the first 8-week post-TKA where rehabilitation usually occurs. Such data would be helpful to physiotherapists for the detection of

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atypical recoveries. In this context, the objectives of the present study are to establish reference values for pain and knee range of motion during the first 8-weeks following a primary TKA and to describe the exercises that were the most prescribed by the physiotherapists using a functional approach for rehabilitation.

Materials and Methods

Study design

This study was part of a large randomized controlled trial, which aimed at assessing the non-inferiority of telerehabilitation interventions to home visits following TKA. Patients were block randomized into 2 groups after surgery: Telerehabilitation (TELE) group or Standard home-visits (STD) group. Detailed methodology and clinical efficacy of this trial is published elsewhere; please refer to Moffet & al, 2015 for further information [18]. This was a multicentric study and it was approved by each participating hospital's Ethics Committee (Trial registration: clinical-trials.com, ISRCTN66285945). The study design can be observed in Figure 1. Clinical signs and symptoms (pain and knee ROM) were assessed by the treating physiotherapists before each treatment session during the intervention period.

Participants

Participants were recruited from the surgical waitlists for primary TKA in eight different hospitals located in the province of Quebec, Canada. Patients were eligible to participate if they met the corresponding selection criteria: (1) expecting a primary TKA for an osteoarthritis condition, (2) planning to return home after hospital discharge, (3) living in an area supplied by high-speed Internet services, and (4) living within a 1-hour driving distance from the treating hospital. Participation was not possible if they: (1) had compelling health conditions that could interfere with assessments or treatment program, including other surgery to the lower limbs for the last 9 months, (2) were waiting for a second lower limb surgery in the next 4 months, (3) had cognitive or collaboration impairments, (4) developed major postoperative complications, or (5) had severe weight-bearing limitations for longer than 2 weeks after surgery. Written consent was obtained for all participants.

Intervention

PT intervention began within 5-days of hospital discharge and lasted 8 weeks. It included bi-weekly 45- to 60-minutes treatment sessions; these sessions are referred to as T1 to T16. Both groups received a comparable, intensive functional approach [14]. PT intervention was conducted according to a standardized guide including exercises from four different categories: Mobility, Strength, Function and Balance. Mobility exercises comprised active ROM exercises in flexion and extension, and general stretching for the lower limbs. They were initially performed seating, but were quickly progressed to standing, adding more weight-bear to the operated side. The Strength category focused on the knee flexors and extensors, with a few additional exercises for ankle and hip muscles. Strength exercises comprised both open and closed-kinetic chain exercises, in addition to added resistance with elastic bands. The Function category included the practice of transfers such as sit-to-stands. Gait training, with or without walking aids, was performed inside and/or outside of the patient's home. Finally, exercises such as unilateral stance with

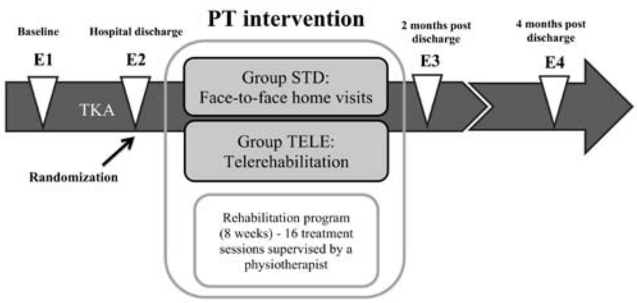

Figure 1: Study design.

progressively decreasing support and wide-stepping were part of the Balance category. Other modalities could be recommended to address individual needs, such as the use of ice, or scar and patellar auto-mobilizations. Home exercises were instructed by the physiotherapist at the end of each session. Patients could refer to the standardized guide when doing their home exercises (eAddenda 1). To ensure comparable intensity and appropriateness of exercises during sessions, physiotherapists had to make certain that the intervention did not increase knee edema or pain. At the end of every session, the physiotherapist noted the prescribed exercises and recommendations in the patient's notebook.

Participants from the TELE group received the treatment sessions through a videoconferencing system (Tandberg 550 MXP, Cisco Systems, San Jose, California), which included a pan-tilt-zoom camera. A technological platform, that involved various components, was installed at both the patient's home and at the clinician site. The system was mounted over a 20-inch LCD screen with external speakers. The clinician controlled remotely the wide-angle lens camera using a dedicated software. Video and audio data were encrypted to ensure confidentiality. High-speed Internet connection was necessary for real-time bidirectional interactions. This platform has been tested and described in previous studies [18,19].

Outcome measures

Pain: Pain is recognized as a frequent symptom experienced by patients after TKA that is important to address as persisting pain has been associated to long-term dissatisfaction at 2 and 5-year post-TKA [20,21]. A 10-cm visual analog scale was used by physiotherapists to assess pre-treatment pain intensity. This test has been validated for the arthritic population (construct validity r = 0.62-0.91) [22], and is a readily available tool to use in a clinical setting [23] with excellent test-retest reliability (Pearson r = 0.71-0.94) [24].

Range of motion: Knee Range of Motion (ROM) in flexion and extension was measured using goniometry at the beginning of every session. Goniometry is a practical tool to measure joint angle using two lever-arms which presents high intra-tester (ICC = 0.99 for flexion, 0.97 for extension) and inter-tester (ICC = 0.98 for flexion, 0.89 for extension) reliability [25]. Criterion validity for the goniometer has been demonstrated higher in flexion (r = 0.97) than extension (r = 0.39) [25], but is a very easily accessible tool for all physiotherapists and is used widely. Additionally, good interrater agreement has been found for assessing knee range of motion with a goniometer in a telerehabilitation context for both knee flexion (0.87) and extension (0.85) using Kripendorff's alpha estimates [26].

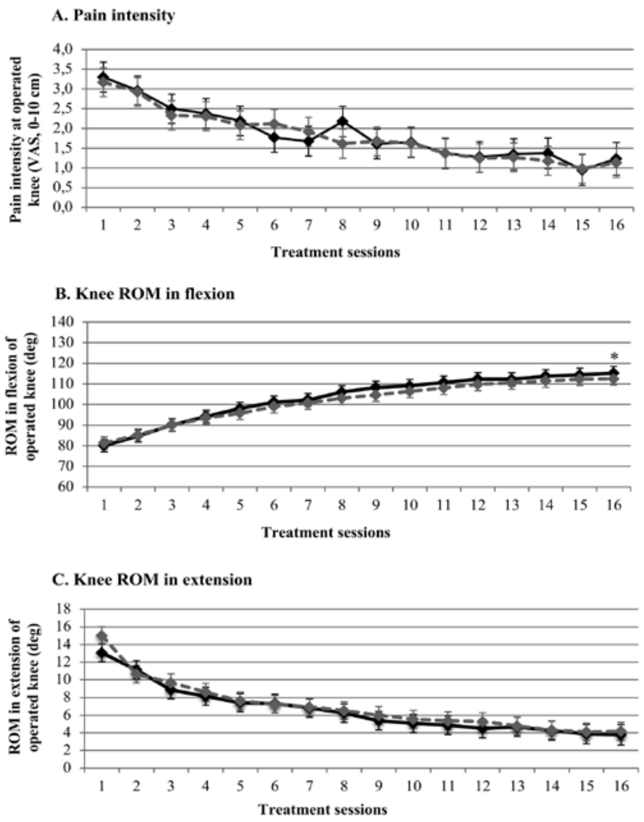

Figure 2: Mean and confidence interval for changes in clinical outcomes at operated knee for TELE (black) and STD (grey) groups throughout PT treatment sessions. Number of days since surgery for each treatment session: T1=10.6±3.3, T2=14.1±3.8, T3=17.7±4.0, T4=21.0±4.3, T5=24.6±4.2, T6=28.0±4.5, T7=31.7±4.6, T8=35.1±4.9, T9=38.9±4.8, T10=42.5±4.9, T11=46.3±5.0, T12=49.6±5.0, T13=53.5±5.2, T14=56.8±5.4, T15=60.6±5.4 and T16=63.6±5.3. *: statistically significant difference between groups.

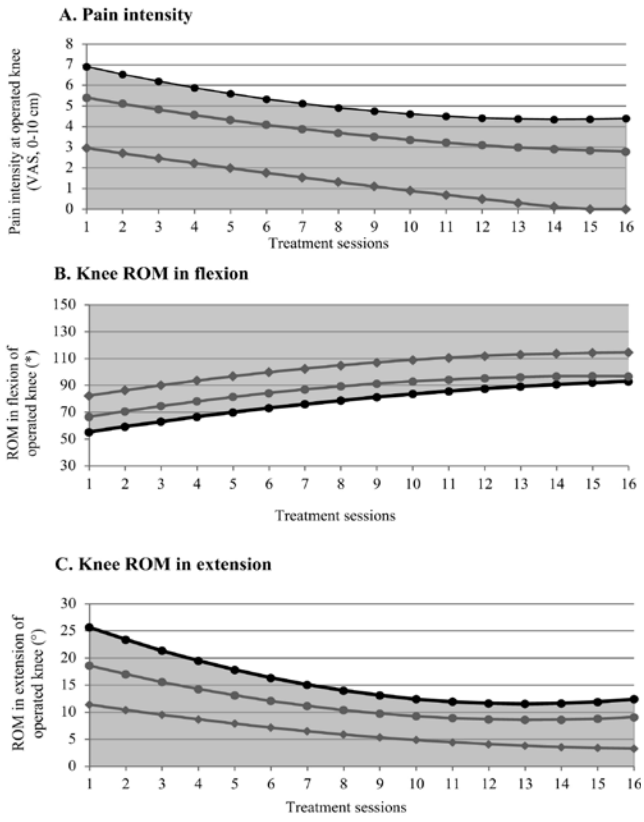

Figure 3: Reference values for changes in clinical outcomes at operated knee for n=197 at the 50th (grey diamonds), 85th (grey dots) and 95th (black dots) percentiles. Shaded areas comprise all values within reference values. Please refer to Figure 2 for number of days since surgery for each individual treatment sessions. The curves were derived from the parameters of the fitted quadratic regression provided in Table 2. For example, the 50th percentile of Pain intensity at session 10 is obtain by calculating: 3.22-0.26×10+0.0028 ×102 = 0.90.

Data analysis

To answer our primary objective, we first performed a one-way ANOVA with Group as factor and treatment sessions as repeated measures on each of our three main clinical outcomes (pain, knee ROM in flexion and extension) to estimate means with Confidence Intervals (CI) within each group (TELE and STD). Second, given that there was no significant Group effect detected in the previous ANOVAs, percentiles were calculated from the whole sample to obtain the 50th, 85th and 95th percentile values for T1 to T16. Third, a regression analysis was carried out using the 50th percentile values as the dependent variable and the treatment session as the independent variable in a model allowing for a quadratic relationship between session time and the 50th percentile. Fourth, the above quadratic regression was repeated with the 85th and 96th percentile values.

For the second objective, a descriptive analysis of the performed exercises (number and percentage) was conducted and reported in a table. To qualify these proportions, we used the following index to classify proportions of patients performing the exercises: "high" for percentages higher than 75%, "good" for percentages between 50% and 74%, "moderate" for percentages between 25% and 49%, and "low" for percentage of 24% or less. In addition, figures representing the distribution of the proportions of several exercise modalities over treatment sessions are presented for additional visual appreciation.

Results

Flow of participants

A total of 198 patients completed the study from the 206 initially randomized, and from which 197 received the PT intervention (1 person refused the intervention, but participated to all assessments from the study). Participant's baseline characteristics were similar in all aspects, except for more participants in the TELE group living alone or having comorbid conditions such as asthma and depression. Detailed personal and sociodemographic data are provided in Moffet et al [18]. Participants retained in the intention-to-treat analysis completed a mean (±1SD) of 15.6±1.9 treatment sessions (STD: 16.0±0.2, TELE 15.2±2.7), which is 97% of the 16 planned sessions. No difference between groups was found for number of days between treatment sessions during all PT intervention period. A significant difference was found for the mean number (±1SD) of days between hospital discharge and the first treatment session: it took almost 2 more days for the TELE group to receive their first session (TELE: 5.5±2.6 days, STD: 3.7±2.0 days, p<0.0001). There was no difference for the duration of the direct contact between the participant and the physiotherapist during treatment sessions, as demonstrated by

Table 1: Number (proportion) of the whole cohort of participants (n=197) who received PT intervention at 3 different time points.

Exercises and modalities from the PT intervention	T1-T2†	T8-T9	T15-T16
Category 1: Mobility exercises			
Flexion ‡	190 (96)††	138 (70)	99 (50)
Extension ‡	184 (93)	146 (74)	108 (55)
Stretching exercises for calves and hamstrings	82 (42)	79 (40)	65 (33)
Category 2 : Strengthening exercises			
Knee extensors ‡	146 (74)	164 (83)	164 (83)
Knee flexors ‡	78 (40)	120 (61)	99 (50)
Ankle plantar flexors	59 (30)	95 (48)	85 (43)
Muscles of the hip (abd/adductors)	34 (17)	60 (31)	42 (21)
Upper extremities	23 (12)	14 (7)	14 (7)
Category 3 : Functional exercises			
Sit-to-stand transfers	86 (44)	89 (45)	57 (29)
Weight-shifts	81 (41)	67 (34)	46 (23)
Gait with walking aid	82 (42)	36 (18)	9 (5)
Gait training without walking aid	11 (6)	51 (26)	51 (26)
Simple gait training ‡	88 (45)	80 (41)	59 (30)
Advanced gait training ‡	1 (1)	56 (28)	69 (35)
Small stationary bicycle ‡	91 (46)	107 (54)	44 (22)
Upright stationary bicycle ‡	0	28 (14)	78 (40)
Step exercises: up-and-down ‡	16 (8)	123 (62)	104 (53)
Stairs: up-and-down ‡	14 (7)	45 (23)	56 (28)
Category 4 : Balance exercises			
Unipodal stance ‡	39 (20)	107 (54)	106 (54)
Bipodal stance ‡	2 (1)	4 (2)	16 (8)
Proprioception with foot-gliding on a towel	25 (13)	42 (21)	66 (34)
Other modalities			
Application of ice	20 (10)	9 (5)	7 (4)
Scar mobilisations	13 (7)	35 (18)	9 (5)
Patella mobilisations	4 (2)	6 (3)	5 (3)

† T1-T2: Treatment session number 1 (10.6±3.3 days post-op) and 2 (14.1±3.8 days post-op), T8-T9: Treatment session number 8 (35.1±4.9 days post-op) and 9 (38.9±4.8 days post-op), T15-T16: Treatment session number 15 (60.6±5.4 days post-op) and 16 (63.6±5.3 days post-op).

†† 190 patients have done the exercise at either T1-T2, or both, which represents a proportion of 96%.

‡ See Figure 5 for illustrated evolution of proportions over time for these interventions.

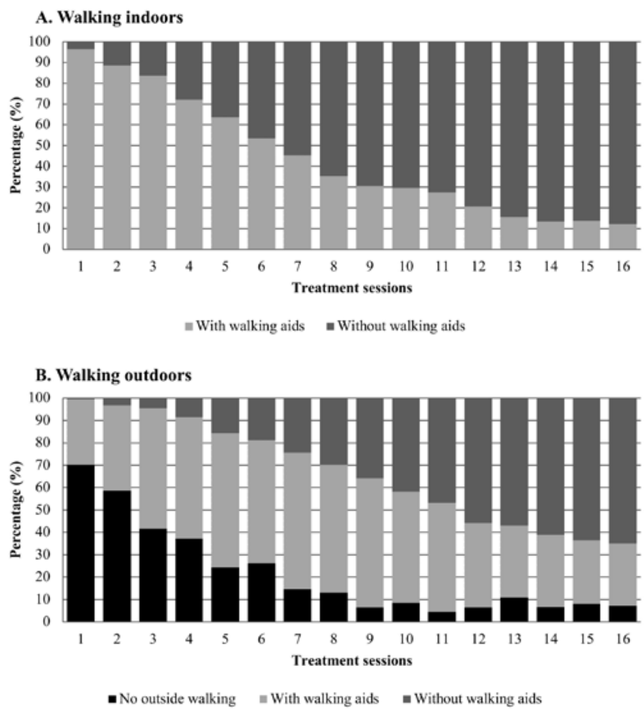

Figure 4: Percentages of patients using a walking aid for indoor and outdoor walking for each treatment session during the rehabilitation period. Please refer to Figure 2 for number of days since surgery for each individual treatment sessions.

Table 2: Parameters of the fitted quadratic regression obtained for each outcome at 50th, 85th and 95th percentile values.

		Parameters of the fitted quadratic regression †		
Outcome	**Percentile**	**α**	**β_1**	**β_2**
Pain intensity	50th	3.22	-0.26	0.0028
	85th	5.72	-0.33	0.0089
	95th	7.32	-0.42	0.01
Knee ROM in flexion	50th	78.11	4.44	-0.14
	85th	62.2	4.62	-0.15
	95th	51.17	4.3	-0.1
Knee ROM in extension	50th	12.45	-1.06	0.03
	85th	20.29	-1.77	0.07
	95th	28.1	-2.54	0.1

†Parameter estimates from the quadratic equation: y= α+ β_1 x+β_2 x^2 where, y is the 50th percentile and x is the treatment session.

similar direct clinical costs in both groups [27].

Clinical outcomes

Pre-treatment clinical outcomes are illustrated in Figure 2 (A-C). Pain intensity remained low in both groups during all sessions (Figure 2A) and diminished similarly between groups from T1 (Mean [CI]; TELE: 3.3 [2.9, 3.7], STD: 3.2 [2.8, 3.5]) to T16 (TELE: 1.2 [0.8, 1.6], STD: 1.1 [0.8, 1.5]). No significant intergroup difference was found at any point for pain. Both groups improved over time for knee ROM in flexion (Figure 2B). While no significant differences can be found from T1 to T15, the participants from TELE group demonstrated a statistically significant greater knee ROM in flexion at T16 (TELE: 110.2 deg ±0.9, STD: 109.3 deg ±0.9). As a 1 deg difference does not exceed error of measurement [28], all participants were pooled together for further analysis. Both groups improved similarly from T1 (TELE: 13.1 deg [12.1, 14.1], STD: 15.0 deg [14.0, 16.0]) to T16 (TELE: 3.8 deg [2.6, 4.9], STD: 4.2 deg [3.2, 5.2]) for knee ROM in extension (Figure 2C).

With both groups revealing similar clinical outcomes from T1 to T16, reference values were established using the entire sample (n=197) for pain, knee ROM in flexion and extension for the first 2-months

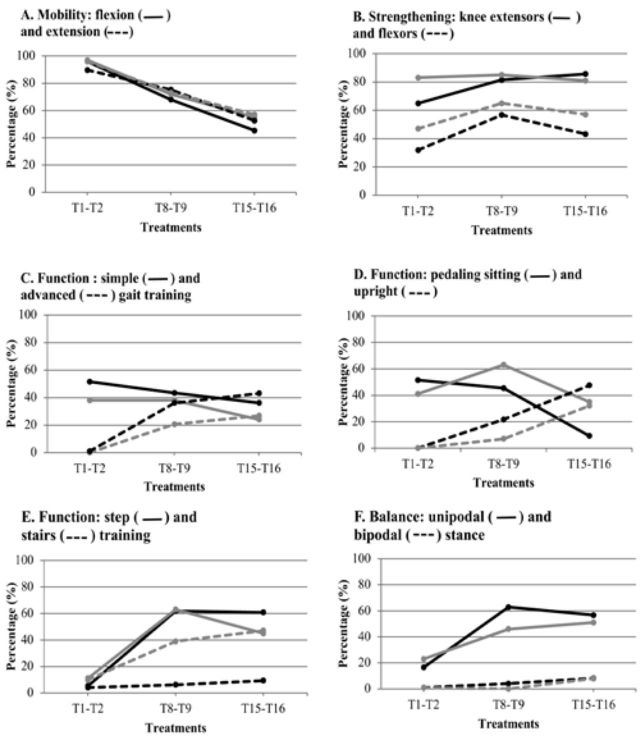

Figure 5: Proportion of participants of the TELE group (black) and the STD group (grey) practicing an exercise at the beginning (treatments 1 and 2: T1-T2), middle (T8-T9) and end (T15-T16) of rehabilitation period. Please refer to Figure 2 for number of days since surgery for each treatment session presented.

post-hospital discharge. These can be observed in Figure 3 (A-C). All values above the 95th percentile in these Figures are considered outliers and thus, suboptimal. To complete, Figure 4 illustrates that >50% of participants were found to walk indoors without a walking aid from T7, and a similar proportion is found to walk outdoors without aid at T12.

Physiotherapy intervention

A detailed list of prescribed modalities can be found in Table 1. The only 2 exercises that were practiced by a "high" proportion of participants during early phase of rehabilitation were from Category 1. Indeed, exercises for knee mobility in flexion and extension were done by virtually all participants at T1-T2 (flexion: 96%, extension: 93%), which decreased over time with only half of subjects still practicing them by the time of T15-T16 (Figure 5A). Training knee extensors strength, a Category 2 exercise, was practiced by a "high" proportion of participants from T8-T9 (83%), until T15-T16 (83%). It appears that knee extensors strengthening was considered important throughout all treatment sessions, with over 74% of all participants doing such exercises during the whole PT intervention (Figure 5B).

Most Category 3 functional exercises, such as weight-shifts and transfers, were practiced by a "moderate" proportion of participants throughout the sessions. We can observe from Table 1 that the proportion of participants receiving gait training using a walking aid decreases steadily from 42% at T1-T2, down to 5% at T15-T16. Logically, the opposite is seen for gait training without a walking aid, from only 6% of participants at T1-T2 to 26% at T15-T16. A very similar pattern is observed for simple and advanced gait training, which progressions over treatment sessions can be appreciated in Figure 5C. Cycling was another functional exercise, which was practiced by a higher proportion of participants in a sitting position during initial and intermediate rehabilitation phase (46% at T1-T2, 54% at T8-T9) compared to the final treatment sessions (22%). The contrary is observed for cycling on an upright stationary bicycle, showing a greater proportion of participants by the end of rehabilitation period (T1-T2: 0%, T15-T16: 40%). Proportions of participants per group for both cycling training can be appreciated in Figure 5D. We can observe from Figure 5D that the number of participants practicing cycling over time is comparable between groups, yet it seems that the TELE group might have shifted from sitting to upright cycling a little sooner than the STD group. Capacity to climb up and down a step was trained in both groups, mostly during the intermediate (62% of participants at T8-T9) and end-phase (53% at T15-T16). For stepping up-and-down exercises (Figure 5E), it is apparent that more subjects from the STD group were doing their training in stairs than the TELE group, who mostly pursued this type of training on a step.

Finally, the most widely practiced exercise from the Balance category was unipodal stance, which was included in the intermediate- and end-phase sessions (T8-T9: 54%, T15-T16: 54%). Bipodal stance was only performed by a low proportion of participants during the whole rehabilitation period. Both exercises are represented in Figure 5F. Overall, most exercise profiles were progressed in a similar fashion for each group, with the exception of training in stairs which was practiced by a greater proportion of participants from the STD group.

Discussion

The first objective of this imbedded study was to determine reference values for readily accessible clinical outcomes, such as pain and knee ROM in flexion and extension, for the first 2-months post-hospital discharge after a primary TKA. As no clinically significant difference was determined between TELE and STD groups for these variables, reference values presented were determined based on the whole sample of 197 patients. Only few data on clinical outcomes can be retrieved for the same period following a primary TKA, but the reference values presented in this paper seem to be in accordance with them. In a study by Bruun-Volsen & al [29], patients who received a primary TKA and practiced active exercises demonstrated pain intensity of 40±21mm on a 100mm VAS scale at 1-week post-surgery, and of 19±15mm at 3 months. Despite the difference in the reference time-period, these results fall between the 50th and 85th percentile presented in our study, which reflects typical evolution for this outcome. A more recent study by Mutsuzaki et al presented target values for knee ROM after TKA in a small prospective cohort. Amplitude for knee flexion at 2-weeks (90.6 ± 15.3 deg) and at 1-month (106.8 ± 15.8 deg) post-TKA correspond to the 50th percentile determined by our study and reflect a good evolution for this outcome with their population [30]. As for knee extension, Codine & al published a study where ROM values in extension after a primary TKA for participants receiving an active rehabilitation ranged from 8.9±6.7 deg 10 days after surgery to 2.7±3.7 deg 30 days afterwards [31]. These values represent an evolution close below the 50th percentile according to our results, which would be considered a typical recovery pattern. Reference values presented in our study also seem to agree with results from telerehabilitation studies. The telerehabilitation group from the Russell & al study demonstrated knee ROM in extension of 6.1±4.7 deg at the first treatment session and had improved of an additional 3.5±3.5 deg by the time of the 6th week of rehabilitation.38 According to our reference values, these amplitudes follow a typical evolution. As many have mentioned before, deficits in ROM can lead to long-term functional deficits for patients who underwent a primary TKA for knee osteoarthritis [15-17]. As such, it seems imperative for any clinician to identify quickly any patient whose outcomes are not progressing as expected and these references values could be helpful for early detection of suboptimal progress.

In addition, this study describes the exercises performed during the treatment sessions. As could have been expected, the results of this study show a decrease in the practice of what would be considered easier exercises over time, with increasingly more participants performing exercises of a greater difficulty by the end of the PT intervention, such as cycling upright versus sitting. Overall, participants from both groups followed a similar exercise profile, with the main exception of step training versus stair training. Favoring certain exercises over others, such as in the previous example, probably reflects the limits of the telerehabilitation context. Indeed, it might have been impossible for the therapists to safely assess performance in stairs from the teleconferencing system's point of view and would have favored step training instead.

The present study offers some limitations such as possible small intergroup and/or intragroup discrepancies regarding the taught exercises since they were selected according to each individual's needs. For example, the final decision regarding added resistance, increased weight-bearing on the operated side or augmented intensity of an exercise was left to the treating physiotherapist. Exercise parameters are not presented in this article; they were however documented for all treatment sessions: number of repetitions, exercise strenuousness, duration of exercise, etc. Thus, the exercise profiles illustrated in this paper allow for a general appreciation of the exercises performed during the 2-months post-hospital discharge after a primary TKA, in both contexts of telerehabilitation and standard home visits interventions.

Conclusion

The reference values presented in this paper, calculated upon a large sample including participants receiving either in-home telerehabilitation or face-to-face visits, should allow for early identification of patients with suboptimal recovery and adjustment of the treatment plan in a timely manner when necessary. Most exercises from an intensive functional approach can be prescribed and practiced in the both methods of PT delivery.

Acknowledgements

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Ethical Approval

This descriptive study is embedded in a multicentre study, and every Ethics Committee of participating hospitals approved this study. All participants gave written informed consent before data collection began.

Source(s) of Support

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