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RESEARCH ARTICLE

The immediate and long-term effects of a walking-skill program compared to usual physiotherapy care in patients who have undergone total knee arthroplasty (TKA): a randomized controlled trial

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Abstract

Purpose: To examine the immediate and long-term effects of a walking-skill program compared with usual physiotherapy on physical function, pain and perceived self-efficacy in patients after total knee arthroplasty (TKA). *Method*: A single blind randomized controlled trial design was applied. Fifty-seven patients with primary TKA, mean age of 69 years (SD ± 9), were randomly assigned to a walking-skill program emphasizing weight-bearing exercises or usual physiotherapy. Outcomes were assessed before the interventions started at 6 weeks postoperatively (T1), directly after the interventions at 12–14 weeks (T2) and 9 months after the interventions (T3). Walking was the primary outcome, assessed by the 6 min walk test (6MWT). The secondary outcomes were timed stair climbing, timed stands, Figure-of-eight test, Index of muscle function, active knee range of motion, Knee Injury and Osteoarthritis Outcome Score and self-efficacy score. *Results*: From T1 to T2, a better 6MWT score was found in favor of the walking-skill program of 39 m (2–76), $p = 0.04$. The difference between the groups in 6MWT persisted at T3, 44 m (8–80), $p = 0.02$. No differences in other outcome measures were found. *Conclusion*: The walking-skill program had better effect on walking than usual physiotherapy. Weight bearing was tolerated.

Keywords

Exercise, knee arthroplasty, physiotherapy, rehabilitation, walking skills

History

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➤ Implications for Rehabilitation

- Weight-bearing exercises are tolerated by the patients in the early stage after TKA.
- Physiotherapy that focuses on learning different ways of walking through practice may be a plausible way to train patients after TKA.

Introduction

With an aging population, the number of patients with knee osteoarthritis that need total knee arthroplasty (TKA) continues to increase [1]. Patients report that their main expected postoperative outcomes are pain reduction, a return to normal daily function and a physically active life [2]. Despite substantial pain relief [3], patients may have impaired balance [4–6], diminished walking speed [7], and difficulties with walking long distances and climbing stairs several months after their operations [3,8]. This indicates that patients may not necessarily achieve their desired physical functional outcomes after TKA.

Most patients undergo physiotherapy in the form of exercises during the first few months after surgery. Physiotherapy aims to maximize or restore physical function essential to everyday life [9]. Walking is a central part of day-to-day activities, and includes, for example, the ability to walk on even and rough, uneven grounds, walk while changing speed and direction, and overcoming obstacles. However, a systematic review shows that exercise programs designed for patients with TKA have minor improvements on walking [10]. To a great extent, the exercise programs studied in the review appeared to include exercises to increase the range of motion of the knee and to strengthen the muscles of the knee joint mostly in lying or sitting positions with rather few exercises performed in weight-bearing positions and involving ambulatory activities [10]. In clinical physiotherapy, there seems to be an assumption that improvements in knee range of motion are closely related to the patient's walking ability. The results from this review [10] may question such an assumption. Further one may raise the question whether an exercise program focused on practicing a variety of walking tasks may be more efficient than muscle strengthening and range of motion training to improve the patients' walking and transfer ability. This has been reported for patients with stroke [11]. However, walking and transfer training involve considerable weight bearing. Thus, it may be a risk that extensive training in weight-bearing positions during the first postoperative months after TKA may induce more pain than training undertaken in mainly non-weight-bearing positions. Further, patients participating in a weight-bearing

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training program may appear to regain less joint range of motion than those receiving targeted muscle strengthening or joint range of motion training.

In spite of these concerns, and to test our assumptions, we designed a walking-skill training program inspired by theories of motor control and learning [12,13]. An important principle of this approach is that motor control is improved through the practice of daily walking tasks in a variety of ways. A further important principle is that motor relearning requires continuous supervision, guidance, feedback and adjustments to performance by the physiotherapist to enable the patients to understand, learn and perform the task properly by, for example, stretching the knee while walking to avoid limping. Practicing everyday walking tasks under close supervision is also assumed, over time, to give patients greater movement confidence, and thereby to improve their perceived self-efficacy in activity. This in turn may motivate the patients to continue practicing the tasks after the completion of the program, ultimately resulting in long-term benefits. We had to closely monitor whether the patients tolerated early weight-bearing exercises or if they lost the improvements otherwise gained by usual physiotherapy care.

The aim of this study was therefore to examine the immediate and long-term effects of a walking-skill program performed during the period of 6–14 weeks after TKA compared with usual physiotherapy care during the same period. The primary outcome was walking distance, and the secondary outcomes were pain, performance-based and self-reported physical function and perceived self-efficacy.

Methods

Study design

The present study is a randomized clinical trial with a follow-up 9 months after the intervention with assessments performed before the intervention at 6 weeks after surgery (T1), immediately after intervention at 12–14 weeks (T2) and, finally, at 9 months after the intervention (T3). Two physiotherapists included the patients and one of them performed all the measurements over time. The physiotherapist did not know which group the patients were allocated to neither did the surgeons and the physiotherapists who treated the patients during the hospital stay. The patients were instructed not to tell the assessor which group they belonged to and as far as we know the concealment was successful.

Before the operation, the patients were invited to participate in the study. Six weeks after the operation, the patients were asked again. If they consented to participation, they were assessed and randomly allocated into two groups: one experimental group that received training in walking skills and one control group that was given usual physiotherapy care. The randomization was undertaken by drawing lots from 70 closed, opaque, sealed envelopes. Half of the envelopes contained a letter indicating the experimental group, while the other half indicated the control group. The physiotherapists who trained the walking-skill group performed the randomization and informed the patients to which group they had randomly been drawn.

The study was approved by the regional Committee for Medical Research Ethics and the Norwegian Social Sciences Data Inspectorate. The study was also registered on Clinical Trials.gov (NCT00807716).

Sample size calculation

The primary outcome variable was assessed by the 6 min walk test (6MWT). According to Perera et al. [14], a change of 20 m in the 6MWT is considered a small meaningful, clinical change while a change of 50 m is considered a substantial, meaningful change in older adults. We estimated the sample size to detect a difference of 50 m between the groups. With a standard deviation of 70 [15], a statistical power of 80% and a significance level of 0.05, each group had to have 30 patients [16].

Participants

All patients admitted for elective primary TKA at two local county hospitals in Norway between November 2008 and June 2010 were considered potential participants in the study. The patients were enrolled consecutively if they fulfilled the following criteria: (1) osteoarthritis of the knee according to diagnostic criteria [17], (2) good written and oral understanding of the Norwegian language and (3) residence close to the hospitals so as to be able to attend the training sessions. To ensure that the patients did not have other walking impairments than those related to their operated knee, patients with rheumatoid arthritis, severe osteoarthritis in the hips or contra lateral knee, neurological diseases, dementia, as well as those with a history of drug abuse were excluded.

Procedures

The surgery was performed by different surgeons, three from one hospital, five from the other. During the surgery, a knee prosthesis, type Low Contact Stress with rotating platform without a patellar component was fitted in place. The operation was performed under spinal anesthesia and the operations were computer assisted to ensure maximal alignment of the joint according to the common procedure at the hospitals involved. While in hospital, patients were given standard physiotherapy according to uniform guidelines, which emphasized exercises mainly to improve joint range of motion, and walking with crutches. The length of the hospital stay was approximately 1 week. All patients were then admitted to a rehabilitation center for 2–4 weeks, where they were given daily, individualized physiotherapy. Thereafter, the patients continued their training in an outpatient physiotherapy department twice a week until they were randomly assigned to either a walking-skill group or usual physiotherapy. Both groups were encouraged to go for walks in addition to training.

The interventions

The walking-skill group

The walking-skill program lasted from 6 weeks to 12–14 weeks after the operation. The training was given in a group. The number of patients in the group varied from two to six, depending on the number allocated at the relevant time. All patients attended 12 supervised physiotherapy sessions with an approximate duration of 70 min per session. The program emphasized ''learning by doing'' with regard to walking and transfer activities and endurance training. Practically, this took the form of training in weight-bearing positions like sideways and forward stepping, walking over obstacles and climbing stairs at different speeds and in different ways, standing and sitting down, throwing a ball while moving, and walking along a 40 m crowded corridor at different speeds and with turns (for details, see Appendix 1). During the sessions, the physiotherapists' thorough supervision, guidance and feedback provided to keep the activities appropriate to each individual's level of physical function and progress over time.

Usual physiotherapy care

The patients in the control group receiving usual physiotherapy care participated in 12 individual physiotherapy sessions, which took place twice a week from 6 weeks to 12–14 weeks after the operation. Information about the contents of the usual physiotherapy care was obtained from exercise logs filled in by the patients according to a structured questionnaire. The questions addressed were whether the patients did exercises of muscle strengthening with weights, range of motion exercises and walking, whether the exercises were performed while lying, sitting, standing or walking, and if the exercises were performed with or without supervision by a physiotherapist. According to the logs, the usual physiotherapy care consisted of a combination of range of motion and resistance exercises; mainly performed while sitting. Only minor parts of the training were performed while standing or walking. Each session lasted approximately 40 min. The physiotherapist treating the patients worked in the vicinity of the hospital. No further information was collected about the physiotherapists.

Demographics

Data on age, BMI, educational level and co-morbidities were collected before the operation. The patients were asked to mark their co-morbidities according to structured questions. The options were angina, diabetes, cancer, osteoporosis, muscle pain, stomach problems, lung disease or mental problems.

Measures

Primary outcome measure of performance-based physical function

The ''6MWT'' was used as the primary outcome measure. The test evaluated the distance walked at a self-selected speed along a 40 m corridor in 6 min. The distance was measured in meters, and more the meters better the result. A walking aid was used if needed. No encouragement was given to the patients during the test. The test has been found to be reliable and valid for older adults [18].

Secondary outcome measures of performance-based physical function

''Timed stair climbing'' is a test to assess the time spent ascending and descending one flight of stairs, in total 16 steps, with a step height of 16 cm. The patients used alternate legs and were allowed to support themselves by holding onto the rail. The time was recorded in seconds, and reduction in time was considered to signify improvement.

The ''Timed-stands test'' assesses a subject's ability to transition from a sitting to a standing position. The patients were asked to rise from and sit down on a chair with a height of 45 cm, 10 times and as quickly as possible, without using the armrests. The time spent was recorded. The test has shown good test–retest reliability, validity and responsiveness for patients with chronic diseases [19].

The ''Figure-of-eight test'' assesses walking balance. A figure of eight was marked on the floor, with an inner and an outer circle. The outer diameter was 180 cm, while the inner diameter was 150 cm. The distance between the outer and inner circles was 15 cm. The patient started the test between the two circles and was told to walk twice around the figure of eight at a self-selected speed without stepping on the lines. The number of steps on or outside the marked lines was counted, the more steps, the worse score. The test has been found to be sensitive, reliable and valid for patients with arthritis in the lower limbs [20].

The ''Index of muscle function'' (IMF) is a functional test that comprises 13 items for evaluating muscle strength, balance and endurance in lying, sitting and standing positions. The index produces a sum score. The worst sum score is 40, while the best is 0. The test has been validated and tested for reliability and sensitivity, mainly for patients with rheumatoid arthritis [21].

''Active range of motion'' is a test that evaluates the total range of movement in the knee using a goniometer [22]. When measuring flexion, the patients lay in a supine position with the knee maximally flexed and with the fulcrum of the goniometer aligned with the lateral midline of the femur using the greater trochanter for reference. The distal arm of the goniometer was aligned with the lateral midline of the fibula using the lateral malleolus for reference. The goniometer alignment was identical when measuring knee extension. While the patient was in a supine position, the knee was extended and a 4 inch rolled towel was placed under the ankle of the leg being examined. The patient was then asked to straighten the knee as far as possible, and the extension measurement beyond the 0 position was measured [22]. The sum of flexion and extension was the total range of motion.

Secondary outcome measures of self-reported physical function and pain

A ''Knee Injury and Osteoarthritis Outcome Score'' (KOOS) is a self-report questionnaire that assesses knee pain and functional knee problems. The test comprises five subscales: pain, symptoms, function in daily living, function in sport and recreation and knee-related quality of life. KOOS is used over both long and short intervals to assess changes, and is considered valid and reliable [23]. A score of 100 indicates ''no problems'', while a score of 0 indicates ''extreme problems''. A change beyond 10 points is considered as clinically relevant in any of the sub items of KOOS [24].

Self-efficacy in activities

A self-efficacy scale for activity was developed by the authors, and was inspired by the theory of Bandura [25]. Bandura suggests that self-efficacy for activities is best evaluated when the questions are tailored to the actual domain evaluated. The scale contains 10 questions focused on the degree to which patients feel safe in performing ambulation and transfer activities like bending down to the floor, kneeling, squatting, ascending several flights of stairs without using a handrail, crossing an intersection on time, shopping in a crowd, walking 2 km on uneven ground, avoiding falls indoors, avoiding falls outdoors and living an active life. Each question features a scale from 0 to 10, where 0 is ''very uncertain'' and 10 is ''very certain'' in coping with the activity in question. The responses to each question were added up to calculate a sum score (0–100). The responses of the self-efficacy scale were tested and found to have a good internal consistency, with a Cronbach alpha coefficient of 0.83. As different self-efficacy scales comprise different items [25,26], an agreed minimal clinically relevant change is unavailable.

Data analysis

The data were analyzed using the Statistical Package for Social Sciences (SPSS, Chicago, IL), version 18. Descriptive statistics for continuous data are given as mean values with standard deviations (SD). The chi-square test was used to analyze differences between groups at T1 with respect to categorical data. Normally distributed continuous data were analyzed using an independent sample *t*-test. In analyzing data over time, missing data were treated according to the principle of intention to treat [27]. Accordingly, for one patient who withdrew during the walking-skill intervention, data at T1 were carried forward to T2. T1 data was also lacking for one patient in the walking-skill group, and this was resolved by carrying back data from T2 to T1. Four patients in the usual physiotherapy care group did not attend for measurements at 9 months after the intervention, and measurements from T2 were therefore carried forward to T3.

Changes within the groups were first analyzed by paired sample *t*-tests. There was a tendency that the walking-skill group had systematically better scores in the outcome variables at T1 than the usual physiotherapy care group. There was also a trend toward more women in the walking-skill group. Therefore and in accordance with recommendations [28,29], differences between groups at T2 and T3 were examined by an ANCOVA analysis using a general linear model to control for baseline scores and gender. Thus, the scores at T2 and T3, respectively, were entered as the dependent variables while group variable, gender and each of the T1 scores were entered as covariates. There was also a tendency that the walking-skill group was better regarding educational level, which may have an impact on how patients respond to questionnaires [30]. Therefore, in the analysis of the self-reported measures, the educational variable was also added as a covariate in the model. These results are given as adjusted means and their confidence intervals (95% CI) and their eta square effect sizes to aid in the interpretation of the data. A partial eta square value between 0.01 and 0.05 is considered a small effect, between 0.06 and 0.13 a moderate effect and between 0.14 and 1 a large effect [31]. The level of statistical significance was set at 5%.

Results

One hundred and one patients met the inclusion criteria and were invited to participate before surgery. Twenty declined the invitation. At 6 weeks post-surgery, 81 patients were invited for participation. Twenty-four patients refused (Figure 1). There was no statistically significant difference between the patients who refused to participate and the ones enrolled in the study with respect to age, educational level, BMI or any outcome measure taken before surgery (data not shown). In total, 57 patients were included in the analysis, 29 in the walking-skill group and 28 in the usual physiotherapy care group. There were no statistically significant differences between the walking-skill group and the usual physiotherapy care group with regard to demographical variables or any of the outcome measures at T1 (Tables 1 and 2).

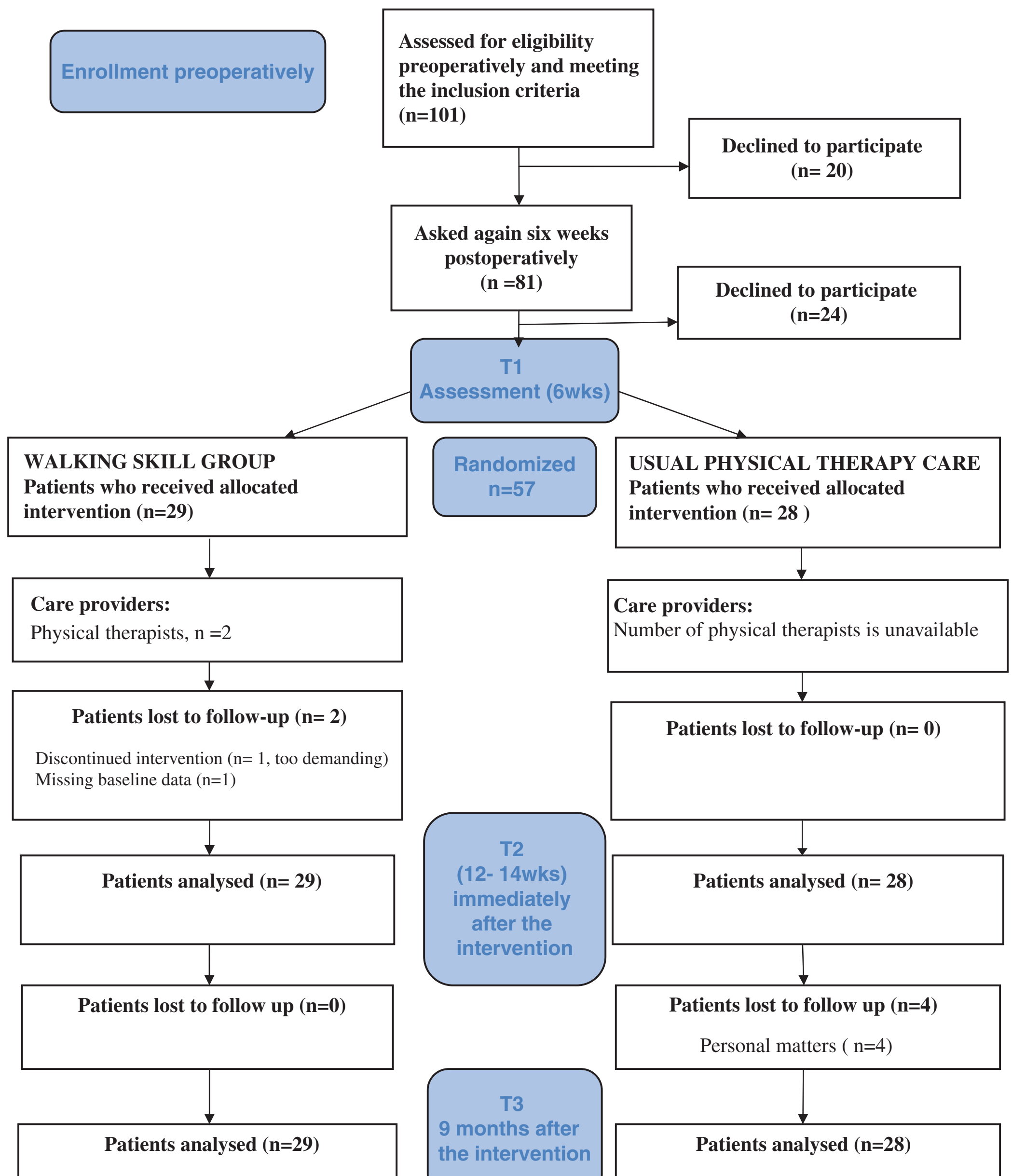

Figure 1. Flow diagram of the participants through the study.

In 6MWT, no statistically significant difference was found in change scores between the two groups from preoperative measures to 6 weeks (T1). During this time span, the walking-skill group declined 80 m, SD ± 86 and the usual physiotherapy care groups declined 67 m, SD ± 69, $p = 0.52$.

Effects immediately after the interventions

Both groups improved in most outcome measures from T1 to T2 (Table 2).

In the primary outcome measure, 6MWT, a statistically significant difference in change scores between the two groups from T1 to T2 was found in favor of the walking-skill group $p = 0.04$, with an effect size of 0.07. No statistically significant differences between the groups in any of the secondary performance-based outcome measures were found.

In KOOS sports and recreation, a statistically significant difference in change scores between the two groups was found in favor of the walking-skill group, $p = 0.008$, and with an effect size of 0.13. In the perceived self-efficacy in activity score, a statistically significant difference in change scores between the two groups was found in favor of the walking-skill group, $p = 0.03$ with an effect size of 0.08.

Table 1. Characteristics of the patients groups with TKA.

	Walking-skill group ($n = 29$)		Usual physiotherapy care ($n = 28$)		
	Mean (SD)	*n*	Mean (SD)	*n*	*p* Value
Characteristics					
Age (years)	68 (8)		69 (10)		0.599
BMI	28 (6)		29 (5)		0.987
Gender (males/females)		11/18		14/14	0.515
Education >12 years		20		13	0.084
Co-morbidities		16		19	0.315
Angina		1		2	
Diabetes		1		1	
Cancer		3		8	
Osteoporosis		0		1	
Muscle pain		7		1	
Stomach problems		1		6	
Lung diseases		1		0	
Mental problems		2		0	

BMI = body mass index.

Effects 9 months after the interventions

In 6MWT, from T1 to T3, there was a statistically significant difference in change scores between the two groups in favor of the walking-skill group, $p = 0.02$, with an effect size of 0.10. In the 6MWT, there was no statistically significant difference in the change scores between the two groups from T2 to T3.

Discussion

Both the walking skill and the usual physiotherapy care groups improved in most outcome measures during the observational period. A statistically significant difference in walking distance was found in favor of the walking-skill group immediately after the interventions that persisted 9 months after the intervention. There were no differences between the groups in other performance-based outcome measures. The walking-skill program seemed to be tolerated by the patients.

The two groups did not differ in their clinical course in walking from preoperatively to the start of the exercise study. However, the interventions seemed to make a difference in walking distance as the walking-skill group walked further than the usual physiotherapy group both directly after the intervention and 9 months afterward. A study examining the effects of functional physiotherapy on walking, compared to usual care in the same time span as the present study [32], found only small effects on walking immediately after intervention, and no effect after 12 months. The content of functional physiotherapy in the mentioned study was much in line with the content in the present usual physiotherapy care program, with exercises in sitting and standing with some walking included, but with a training duration similar to the walking-skill program. Our walking-skill program contained different and more vigorous exercises in weight bearing than the mentioned study [32] and the participants gained somewhat more in walking. Consequently, the findings from the present study are promising. To double check the results, the data were also analyzed without the missing patients included. Then the difference between the groups increased slightly. Thus, the dropouts had minor impact on our results.

Table 2. The short-term (T1–T2) and long-term (T1–T3) effects of a walking-skill intervention in patients with TKA.

	Walking-skill group ($n = 29$)			Usual physiotherapy care ($n = 28$)			Adjusted differences between groups Mean (95% CI)	Adjusted differences between groups Mean (95% CI)
	Mean (SD)			Mean (SD)				
	T1	T2	T3	T1	T2	T3	T1–T2	T1–T3
Performance-based								
6MWT (m)	368 (89)	477 (92)**	492 (90)	332 (107)	413 (105)**	425 (93)	39 (2, 76)*	44 (8, 80)***
Stair up/down	21 (8)	14 (5)**	14 (8)	24 (14)	15 (7)**	15 (7)	−2 (−7, 3)	0 (−4, 4)
Time stands (s)	35 (17)	30 (6)	29 (7)	37 (13)	31 (10)	32 (13)	−2 (−7, 3)	−2 (−7, 3)
Figure eight (steps)	14 (11)	12 (13)	9 (11)	15 (14)	14 (14)	12 (12)***	−2 (−8, 3)	−4 (−8, 1)
IMF[a]	15 (6)	10 (6)**	11 (7)	17 (7)	11 (6)**	12 (7)	1 (−2, 4)	−1 (−3, 2)
ROM (degrees)[b]	98 (15)	110 (13)*	118 (7)****	93 (20)	104 (12)*	114 (17)****	−2 (−4, 7)	1 (− 4, 7)
Self-reports								
KOOS Symptoms	60 (14)	71 (17)**	80 (19)***	52 (18)	60 (17)*	73 (21)****	5 (−2, 13)	2 (−9, 13)
KOOS Pain	61 (16)	74 (21)**	82 (21)	54 (18)	65 (21)*	74 (23)	2 (−7, 11)	0 (−9, 10)
KOOS Function	64 (21)	79 (19)**	81 (18)	60 (17)	71 (18)**	75 (21)	3 (−2, 10)	1 (−8, 7)
KOOS Recreation	35 (11)	45 (25)*	47 (27)	32 (14)	26 (25)	36 (30)	14 (3, 25)*	8 (−7, 22)
KOOS QOL	44 (20)	65 (22)**	72 (24)	35 (21)	50 (21)**	62 (26)***	9 (−2, 20)	5 (−7, 17)
Self-efficacy	51 (21)	75 (17)**	75 (21)	47 (24)	63 (23)**	66 (27)	10 (2, 17)*	6 (−4, 16)

[a]Index of muscle function; [b]Range of motion. T1 = preintervention, T2 = immediately after the intervention, T3 = 9 months after the intervention from T1 to T2.

*$p < 5\%$; **$p < 1\%$ from T1 to T3; ***$p < 5\%$; ****$p < 1\%$.

An important issue, however, is whether the difference in walking distance has any clinical importance. A small meaningful improvement in walking distance is defined as 20 m in older adults while an improvement of 50 m is defined as substantial [18]. Thus the 30–40 m of additional distance walked by the walking-skill group both directly and 9 months after the intervention was considered being of moderate clinical importance [18]. The effect sizes also suggest the changes to be of moderate clinical relevance [31]. Further, a recent study showed that healthy people in the same age group walked from 530 to 630 m in 6 min [33]. Presently, the walking-skill group approached the lower limits of the reference standards for healthy adults in the same age group 9 months after the intervention. Taking this together, we suggest that the improvement in walking distance in the walking-skill group has clinical relevance. But as this study is the first to introduce that vigorous exercises, more research is needed before definite conclusions can be drawn.

One of the intentions of the walking-skill program was to improve stair climbing. Presently, no difference between the groups in stair climbing time was found. According to other studies, stair climbing is a difficult task to perform in the early phase of recovery after TKA [8], and is supposed to be especially influenced by pain. These findings are consistent with the impression we gained when we trained the patients. Stair climbing was painful and we did not focus as much on the task as we had planned. Thus, limited training of stair climbing in the program may explain the lack of effect. Immediately after the intervention, there were statistically significant improvements in KOOS sport and recreation and self-efficacy scores in favor of the walking-skill group, but these differences were not seen 9 months after the interventions. The immediate effects might be related to differences in content between the two interventions, as an important factor in the walking-skill program itself was to motivate the patients to do ambulatory activities. In turn, this may have made the patients more confident to try out weight-bearing activities on their own at an earlier stage than those in the usual physiotherapy care group. On the other hand, the differences between the groups in self-efficacy and KOOS sports and recreation were rather small, did not persist, and may therefore be of minor clinical importance.

Before we started this study, we assumed that the patients with TKA would tolerate weight-bearing exercises as early as 6 weeks after surgery. Nevertheless, we were concerned that a weight-bearing program could be too challenging for most of the patients with TKA, especially the elder ones. During the program, the elder patients performed well. In contrast to what we originally thought, one of the youngest patients withdrew from the program as he got a swollen knee, and the physiotherapist interpreted that he overdid the exercises. Looking at the two groups as a whole, a similar pain reduction was found in the walking-skill group and the usual physiotherapy care group. Another research group has also reported that there was no difference in pain or stiffness in patients with TKA after doing balance exercises in weight bearing in addition to usual physiotherapy [34]. Another issue we considered initially was whether our patients would lose benefits in range of motion compared with the usual physiotherapy group. However, the patients in the walking-skill group did not lose range of motion in comparison with the gain measured in the usual physiotherapy care group. Altogether, these findings suggest that doing as much as 1 h weight-bearing exercises as early as 6 weeks after surgery is well tolerated by patients with TKA. This also suggests that physiotherapists in the clinics could implement more weight-bearing exercises in their programs for these patients. Further research is needed in the field including more challenging performance-based tasks in physiotherapy training to capture improvements in even more skilled movements and activities after TKA.

Our training program had a focus on achieving walking skills in a broad sense. Retrospectively, one might question whether the choice of the 6 MW test as the primary outcome measure was appropriate. To mirror the challenges embedded in the training program, effect measures should also have reflected walking tasks performed on rough and uneven surfaces as well as walking outdoors. Moreover, we also realize that the 6 MW test could have been optimized if we had instructed the patients to walk as fast as possible rather than at a self-selected speed. On the other hand, one could argue that patients may select their walking speed according to the confidence they have in their walking ability, implying that they walk faster if they are confident. Consequently, we considered self-selected speed to be appropriate, but walking measures should have been complemented with more challenging walking tests.

The study has apparent strengths, such as the clinically controlled design with a long-term observation, high adherence with the interventions in both groups, and the fact that all the measurements were undertaken by the same assessor, who was blinded for group allocation. Some of the measurements were also used in similar studies [32,34] so the internal validity was considered to be rather good. However, there are also methodological limitations. Presently, the randomization was not entirely successful as there was a tendency that the walking-skill group had generally better pretest scores. We have followed recommended procedures to handle this problem statistically [29], and thus made the groups as comparable as possible. Due to slow inclusion and dropouts during the first 6 weeks, the effect study was slightly underpowered for the primary outcome and probably even more for several of the secondary outcome variables, especially in the self-reports a considerable variability within the groups were observed. Thus, a larger sample size might have enabled us to find differences in other variables as well.

An additional important issue is whether the sample is representative, and consequently whether the results can be generalized to other patients with TKA. The patients were recruited, for practical reasons, from an area with a large proportion of relatively highly educated people. However, no association between age, educational level and change in walking length was found (data not shown). Thus, education does not seem to make any difference to their functional status. Compared to other studies, the BMI of the patients in the present study was slightly lower [34], but the age of the study sample was on the same level as in other studies [32] and in the same age group as the population with TKA in Norway [35]. We therefore believe that our patients to a great extent are comparable to those included in other studies and that the results can be generalized to a population of patients with TKA of normal to slightly above average weight.

In conclusion, both the patients in the walking-skill group and the physiotherapy care group improved during the observational period. The group performing the walking-skill program from 6 weeks to 12–14 weeks after TKA showed a statistically significant improvement in walking distance with clinical relevance compared to usual physiotherapy care both immediately after the interventions and at follow-up 9 months after the intervention. To our knowledge, this is the first study to investigate the effect of solely weight-bearing exercises in physiotherapy training after TKA. The lack of negative effects suggests that extensive weight-bearing exercises can be tolerated as early as 6 weeks post-operatively after TKA.

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Declaration of interest

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References

1. National Joint Registry for England and Wales. Annual report. 2012:18–19. Available from: www.njrcentre.org.uk
2. Nilsdotter AK, Toksvig-Larsen S, Roos EM. Knee arthroplasty: are patients’ expectations fulfilled? A prospective study of pain and function in 102 patients with 5-year follow-up. Acta Orthop 2009; 80:55–61.
3. Bruun-Olsen V, Heiberg KE, Mengshoel AM. Continuous passive motion as an adjunct to active exercises in early rehabilitation following total knee arthroplasty – a randomized controlled trial. Disabil Rehabil 2009;31:277–83.
4. Mauer AC, Draganich LF, Pandya N, et al. Bilateral total knee arthroplasty increases the propensity to trip on an obstacle. Clin Orthop Relat Res 2005;433:160–5.
5. Mandeville D, Osternig LR, Chou LS. The effect of total knee replacement on dynamic support of the body during walking and stair ascent. Clin Biomech 2007;22:787–94.
6. Gage WH, Frank JS, Prentice SD, Stevenson P. Postural responses following a rotational support surface perturbation, following knee joint replacement: frontal plane rotations. Gait Posture 2008;27: 286–93.
7. Walsh M, Woodhouse LJ, Thomas SG, Finch E. Physical impairments and functional limitations: a comparison of individuals 1 year after total knee arthroplasty with control subjects. Phys Ther 1998; 78:248–58.
8. Heiberg KE, Bruun-Olsen V, Mengshoel AM. Pain and recovery of physical functioning nine months after total knee arthroplasty. J Rehabil Med 2010;42:614–19.
9. Carr JH, Shepherd RB. Enhancing physical activity and brain reorganization after stroke. Neurol Res Int 2011;2011:515938.
10. Minns Lowe CJ, Barker KL, Dewey M, Sackley CM. Effectiveness of physiotherapy exercise after knee arthroplasty for osteoarthritis: systematic review and meta-analysis of randomised controlled trials. BMJ 2007;335:812.
11. States RA, Pappas E, Salem Y. Overground physical therapy gait training for chronic stroke patients with mobility deficits. Stroke 2009;40:627–8.
12. Shumway-Cook A, Woollacott MH. Motor control translating research into clinical practice. 3rd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2007.
13. Schmidt RA, Lee TD. Motor control and learning a behavioral emphasis. 4th ed. Champaign, IL: Human Kinetics; 2005.
14. Perera S, Mody SH, Woodman RC, Studenski SA. Meaningful change and responsiveness in common physical performance measures in older adults. J Am Geriatr Soc 2006;54:743–9.
15. Boardman DL, Dorey F, Thomas BJ, Lieberman JR. The accuracy of assessing total hip arthroplasty outcomes: a prospective correlation study of walking ability and 2 validated measurement devices. J Arthroplasty 2000;15:200–4.
16. Altman DG. Practical statistics for medical research. London: Chapman and Hall; 1991.
17. American College of Rheumatology. Clinical classification criteria for osteoarthritis of the knee, classification tree format. 1986. Available from: URL:http//www.reumatology.org/practice/clinical/classification/oa-knee/oakneetree.asp [last accessed 1986].
18. Harada ND, Chiu V, Stewart AL. Mobility-related function in older adults: assessments with a 6-minute walk test. Arch Phys Med Rehabil 1999;80:837–41.
19. Newcomer KL, Krug HE, Mahowald ML. Validity and reliability of the timed-stands test for patients with rheumatoid arthritis and other chronic diseases. J Rheumatol 1993;20:217.
20. Noren AM, Bogren U, Bolin J, Stenstrom C. Balance assessment in patients with peripheral arthritis: applicability and reliability of some clinical assessments. Physiother Res Int 2001;6:193–204.
21. Ekdahl C, Andersson SI, Svensson B. Muscle function of the lower extremities in rheumatoid arthritis and osteoarthrosis: a descriptive study of patients in a primary health care district. J Clin Epidemiol 1989; 42:947–54.
22. Norkin C, White J. Measurement of joint motion: a guide to goniometry. Philadelphia, PA: F.A. Davis Company; 1995.
23. Roos EM, Toksvig-Larsen S. Knee injury and Osteoarthritis Outcome Score (KOOS) validation and comparison to the WOMAC in total knee replacement. Health Qual Life Outcomes 2003;1:17.
24. Roos EM, Lohmander LS. The Knee injury and Osteoarthritis Outcome Score (KOOS): from joint injury to osteoarthritis. Health Qual Life Outcomes 2003;1:64.
25. Bandura A. Guide for constructing self efficacy scales: self efficacy beliefs of adolescents. Charlotte, NC: Information Age Publishing; 2006.
26. Lorig K, Chastain RL, Ung E, et al. Development and evaluation of a scale to measure perceived self-efficacy in people with arthritis. Arthritis Rheum 1989;32:37–44.
27. Armijo-Olivo SWS, Magee D. Intention to treat, compliance, drop-outs and how to deal with missing data in clinical research: a review. Phys Ther Rev 2009;14:36–47.
28. van Breukelen GJ. ANCOVA versus change from baseline: more power in randomized studies, more bias in nonrandomized studies. J Clin Epidemiol 2006;59:920–5.
29. Vickers AJ, Altman DG. Statistics notes: analysing controlled trials with baseline and follow up measurements. BMJ 2001;323:1123–4.
30. Arvidsson S, Arvidsson B, Fridlund B, Bergman S. Factors promoting health-related quality of life in people with rheumatic diseases: a 12 month longitudinal study. BMC Musculoskelet Disord 2011;12:102.
31. Pallant J. SPSS survival manual a step by step guide to data analysis using SPSS. 4th ed. Maidenhead: McGraw-Hill; 2010.
32. Moffet H, Collet JP, Shapiro SH, et al. Effectiveness of intensive rehabilitation on functional ability and quality of life after first total knee arthroplasty: a single-blind randomized controlled trial. Arch Phys Med Rehabil 2004;85:546–56.
33. Casanova C, Celli BR, Barria P, et al. The 6-min walk distance in healthy subjects: reference standards from seven countries. Eur Respir J 2011;37:150–6.
34. Piva SR, Gil AB, Almeida GJ, et al. A balance exercise program appears to improve function for patients with total knee arthroplasty: a randomized clinical trial. Phys Ther 2010;90:880–94.
35. Havelin LI, Engesaeter LB, Espehaug B, et al. The Norwegian arthroplasty register: 11 years and 73 000 arthroplasties. Acta Orthop Scand 2000;71:337–53.

Appendix 1: Components of the walking-skill intervention

Weight-bearing tasks with supervision, guidance and feedback	Target	Description and progression
Warm-up with music		Ten minutes of standing with weight transfers, sidesteps with arm swing, walking in a circle at different speeds and step length
Sit to stand	Strength and flexibility	Five minutes of rising from and lowering onto a chair, squats, at different speeds and with weight transfers
Lunges	Strength, stretching and balance	Five minutes of lunges forward and sideways on alternate legs
Single-leg stance	Strength and balance	Five minutes of single-leg stance on alternate legs while moving the other leg
Standing on foam balance pad	Strength and balance	Ten minutes of squats, forward, backward and sideways with increasing angles in hips and knees
Step-up/step-down	Balance, strength and flexibility	Five minutes of ascending and descending a step, forward and backward and at different speeds and different step heights
Stair climbing	Balance, strength and flexibility	Five minutes of going up and down five steps with different heights and at different speeds
Obstacle course	Walking balance	Ten minutes of stepping over obstacles, stepping onto, along and down from an aerobic step and bosu ball, walking over a foam mat and progressing by increasing the speed, height and number of obstacles
Throwing ball	Balance and coordination	Five minutes of throwing and catching a ball to each other in a circle while moving around
Walking	Endurance and flexibility	Five minutes of walking in a crowded corridor at different speeds, step lengths, with turns and progression to maximal walking speed
Stretching	Flexibility	Five minutes of stretching of calf, leg, thigh, neck and shoulder muscles