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RESEARCH PAPER

Continuous passive motion as an adjunct to active exercises in early rehabilitation following total knee arthroplasty – a randomized controlled trial

VIGDIS BRUUN-OLSEN[1,2], KRISTI ELISABETH HEIBERG[1,2] & ANNE MARIT MENGSHOEL[2]

[1]*Asker and Baerum County Hospital, Department of Physiotherapy, and* [2]*Institute of Nursing and Health Sciences, Medical Faculty, University of Oslo, Norway*

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Abstract

Purpose. Continuous passive motion is frequently used post-operatively to increase knee range of motion after total knee arthroplasty in spite of little conclusive evidence. The aim of this study was to examine whether continuous passive motion (CPM) as an adjunct to active exercises had any short time effects (after one week and three months) on pain, range of motion, timed walking and stair climbing.

Method. A randomized controlled trial was conducted. A total of 63 patients undergoing primary TKA were randomly assigned into an experimental group receiving CPM and active exercises and a control group receiving active exercises only. Outcomes were assessed by goniometer, visual analogue scale (VAS), timed 'Up and Go' test (TUG), timed 40 m walking distance and timed stair climbing.

Results. There were no statistical differences between the treatment groups for any outcome measures either at one week or after three months. For the whole group, a significant and 50% reduction in pain score was found after three months ($p < 0.01$). Compared with before surgery, a significantly impaired knee flexion range of motion ($p < 0.01$) and a significantly decreased number of patients able to climb stairs were found after three months ($p < 0.01$).

Conclusion. CPM was not found to have an additional short-time effect compared with active physiotherapy. After three months considerable pain relief was obtained for the whole group, the patients preoperative ROM was not restored and the number of patients able to climb stairs had decreased.

Keywords: *Total knee arthroplasty, continuous passive motion, exercises*

Introduction

Osteoarthritis is characterized by degeneration of the joint cartilage. This can reduce the mobility of the joint, cause pain and limit the patient's walking ability [1]. In serious cases total arthroplasty may be necessary. In 2005 alone, 2780 primary total knee arthroplasties (TKA) were performed in Norway. The average age of the operated patients was 70 and 70% were women [2].

The purpose of TKA is to reduce pain and improve the range of motion (ROM) of the joint. Improvements in these two factors enhance the patient's ability to sit down, rise from a sitting position and climb stairs and thus the rehabilitation process [3]. Since ROM in the early post-operative phase seems to be an important prognostic factor for the patient's walking ability later [4], it is important to achieve the best possible knee ROM while the patient is in hospital. Thus the exercise methods practised in the hospital might have considerable consequences for the patient in the longer term.

In the post-operative phase the exercises supervised by the physiotherapist consist of active movement of the knee and hip. In some hospitals the knee is also moved by a machine in continuous passive motion (CPM) part of the day. However, use of the machine is time-consuming for the hospital staff, and

Correspondence: Anne Marit Mengshoel, RPT, PhD, Professor, Institute of Nursing and Health Sciences, The University of Oslo, Box 1153 Blindern, 0316 Oslo, Norway. Tel: +47 2285 8413. Fax +47 2285 8411. E-mail: a.m.mengshoel@medisin.uio.no

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it is expensive and costly to maintain. Furthermore, we pose the question if the use of CPM aggravates the post-operative pain as we have experienced that some patients find the treatment painful and uncomfortable. This makes it important to discover whether CPM does, in fact, have an additional beneficial effect in relation to active exercises supervised by physiotherapists.

There is little conclusive evidence concerning the short-time benefits of CPM. Milne et al. [5] made a meta-analysis of 58 studies, 14 of which fulfilled the quality criteria for the analysis. The authors investigated the additional effect of CPM in relation to active exercises, and concluded that additional treatment with CPM can lead to a more rapid increase of flexion ROM during the first two weeks after surgery. However, they found no differences in ROM between the two groups after a year. On the other hand in a number of single studies CPM was not found to have a more beneficial effect on range of motion during the first post-operative phase than active exercises alone [6 – 11]. The conflicting results may be due to differences in the dose of CPM [9], but it could also be due to methodological factors such as type 2 errors or insufficient randomization or blinding [9,12,13].

One of the main reasons for using CPM is that the early degree of mobility of the knee is believed to influence the patient's walking ability in the long term. However, in studies of CPM, walking ability is either not measured [14] or assessed only on the basis of self-administered questionnaires [1]. Milne et al. [5] proposed that walking ability should be assessed by objective measures. Thus, presently quantifiable measurements of activities such as rising from a chair, walking on a flat surface and climbing stairs were used.

The aims of the study were to investigate whether CPM had an effect on pain, knee ROM and walking ability above the effect of active post-operative physiotherapy in patients with TKA one week and three months after the operation, and whether there was any association between knee ROM and walking ability.

Method

Study design

The present study was a clinical, controlled, single-blind study. Measurements were taken before surgery (baseline), after one week and after three months. The physiotherapist who performed the measurements did not know which intervention group the patient belonged to. The patients were randomly allocated into two groups with two different post-operative exercise regimes, either CPM together with active exercises (the experimental group) or active exercises alone (the control group). Based on the Altman's nomogram with a standard difference of 0.75 (i.e. a clinical relevant difference of 15° with a standard deviation of 20°) with a power of 80% and a significance level of 0.05, the sample size was calculated to reach 55 patients (for two groups) [15]. The number was set at 70 to take account of any drop-outs. The random allocation procedure was as follows: Seventy closed, opaque envelopes containing the specified treatment regime were prepared beforehand by the researchers, 35 for each group, and the physiotherapist concerned chose an envelope for each patient before starting the post-operative training. The study was approved by the Regional Committee for Medical Research Ethics and the Norwegian Social Science Data Services.

Subjects

All patients with osteoarthritis admitted to Asker and Baerum General Hospital for TKA between October 2003 and March 2005 were sent written information about the study beforehand, together with an invitation to participate. Patients were enrolled consecutively according to the following criteria: Good cognitive function and fluent spoken and written knowledge of Norwegian. Patients with rheumatoid arthritis or prosthesis in the ipsilateral hip were excluded. On the day of admission the patients were asked again if they wished to participate and their consent was obtained in writing.

Procedure

During surgery a knee prosthesis (type LCS with rotating platform) without a patella component was fitted in place. The operation was performed with spinal anaesthesia. The guidelines for administering pain relief were the same for all patients: An epidural pump with a standard dose of marcain/EDA was used for two days. The patients also received paracetamol. When the need for analgesics was greater than normal, the patient received morphine or ketorax.

The post-operative training programme was conducted according to the same guidelines for all the patients. The exercises were performed daily, starting on day one after surgery, lasting for 30 min and the exercises were adjusted to the patient's degree of pain. The exercises consisted of assisted and active flexion and extension of the hip/knee, active isometric contraction of the quadriceps, walking training using a high walker, rollator or crutches, and eventually climbing stairs on crutches. The experimental group was given CPM treatment for the knee in flexion and extension in addition to the active exercises. For the passive movements, the patient lay in a supine position with the operated leg in the CPM machine. On the day of the operation the machine was set at 70 – 100° for flexion and the knee was moved continuously for 2 h × 2. The next day the machine was set at 0° to maximum 100° flexion, and the knee was kept in movement continuously for 2 h × 3. These were the usual clinical procedures in the hospital concerned. Between sessions the knee was placed in the extended position. The patients stayed in hospital for a week, at the end of which they could cope with dressing and grooming and walk alone with a mechanical aid. All the patients followed an exercise programme with a local physiotherapist after discharge. The out-patient treatment was not standardized.

Measures

Pain intensity in the knee was measured by means of a 100 mm visual analogue scale (VAS), where 0 indicated no pain and 100 indicated unbearable pain [16]. The patients marked their perceived pain on a paper. Knee circumference was measured over the joint space and recorded in cm. A change in circumference was used to determine the size of swelling.

Knee ROM in terms of active and passive flexion and extension was measured by a goniometer with the patient in a supine position. Knee flexion was measured with the hip at 90° flexion. The goniometer swivel was placed over the joint space, with one arm aligned with the greater trochanter and the other along the line running from the fibular head to the lateral malleolus of the ankle [17]. The knee was moved to maximum flexion and the range measured in degrees. Extension was measured with the patient in a supine position with the ankle resting on a bolster and the goniometer in the same position as for flexion. The knee was extended maximally and the range measured in degrees. The measurements were taken by two physiotherapists: One moved the leg and the other controlled the goniometer. To obtain the best possible reliability, the physiotherapists rehearsed the procedure beforehand by taking measurements from 10 randomly selected patients at two different times. Discrepancies in measurements between the two physiotherapists and between the measurement times were discussed, and the procedure was refined to ensure greater precision.

Timed 'Up and Go' (TUG) is a test where the patient gets up from a chair with armrests (height 44 – 47 cm), walks forwards for 3 m, turns, walks back and sits down in the chair. We used a Norwegian translation of the test [18], and instructed the patient as follows: 'When I say "ready – go" stand up and walk forwards at a safe, comfortable speed without help to a point three metres away, then walk back to the chair and sit down again'. If necessary the patient used a stick, crutch/crutches or rollator. The patient performed the test twice, and the time taken for the second performance was recorded. A time of 11 – 12 sec is considered normal [19].

The patient was also instructed to walk 40 m down a hospital corridor at a rapid but safe speed. If necessary the patient used an aid such as a stick, crutch/crutches or rollator. The time was measured in seconds. The patient was also instructed to walk up and down a flight of stairs consisting of eight steps with a step height of 16 cm. The patient was instructed to use alternate legs and not to support themselves by holding onto the rail or use a walking aid [20]. Time was measured in seconds.

Statistical analysis

The data were analysed with the Statistical Package for Social Sciences (SPSS), version 12 for Windows and showed a normal distribution. Within-group differences between measurements at the different times were analysed with one-sample *t*-tests and between-group differences with two-sample *t*-tests. Nominal data were analysed with the Chi-square test. Pearson's correlation coefficient was calculated to determine the association between continuous variables. The level of significance was set at $p \leq 0.05$.

Results

All 70 patients who fulfilled the inclusion criteria were invited to participate in the study, and three declined the invitation. Sixty-seven patients participated and these were measured and treated during the period of hospitalization. Four patients, three women and one man, were not measured at three months. Two of them had died from heart and lung disease and two did not attend the follow-up consultation. The data on these four patients were withdrawn from the study, and the results are based on the findings from 63 patients, 44 women and 19 men. The mean age was 69, with a range of 49 – 92. There were no statistically significant differences between the two patient groups at baseline (Table I) and as regards to the use of medication during the period of hospitalization.

The results of the measurements in the two groups at the different times are shown in Table II. There were no statistically significant differences between the two groups with regard to pain, range of motion or swelling at either one week or three months compared with baseline ($p > 0.05$). Nor were there any statistically significant differences between the groups in walking ability as measured by the TUG,

Table I. Characteristics of the patient groups and their preoperative assessments.

	CPM group plus active exercises $n = 30$	Active exercise alone $n = 33$	Group differences p-values
Men/women (%)	27/73	33/67	0.8
Age (years)	68 ± 10	71 ± 10	0.3
Education (years)	11 ± 2	12 ± 4	0.3
Knee circumference (cm)	40 ± 5	40 ± 4	0.5
Pain intensity (VAS 0–100)	52 ± 17	47 ± 19	0.2
Active knee flexion (°)	121 ± 14	127 ± 12	0.09
Passive knee flexion (°)	125 ± 14	131 ± 13	0.06
Active knee extension (°)	−4 ± 6	−4 ± 6	0.5
Passive knee extension (°)	−2 ± 7	−2 ± 6	0.7
Time Up and Go (sec)	12 ± 4	13 ± 6	0.2
40 m walking test (sec)	52 ± 17	47 ± 19	0.7

walking on a flat surface or climbing stairs compared with baseline ($p > 0.05$).

Within each group the range of motion in flexion and extension after one week was significantly smaller than at baseline ($p < 0.01$). After three months, flexion range of motion was greater than at one week, but still significantly lower than at baseline ($p < 0.01$). Within both groups pain intensity was significantly lower after three months than at baseline ($p < 0.01$), but swelling in the knee was more pronounced ($p < 0.01$). The scores for the TUG and the 40 m walking test had returned to baseline values at three months ($p > 0.05$).

There was no statistically significant correlation between the values for knee ROM and the walking tests either at baseline or at three months ($p > 0.05$), or between flexion ROM at baseline and one week, or at baseline and three months ($p > 0.05$). On the other hand, there was a statistically significant correlation between flexion range of motion at one week and at three months ($r = 0.6$, $p < 0.01$).

Before surgery, 21 members of the CPM group could climb the stairs, as opposed to 19 in the control group ($p = 0.4$). At three months 13 members of the CPM group could climb the stairs, as opposed to 15 in the control group ($p = 1.0$). In the group as a whole there was a smaller number of patients ($n = 28$) who were able to climb the stairs at three months than at baseline ($n = 40$) ($p < 0.01$). Those able to climb the stairs at three months had significantly less pain ($p = 0.04$), better active flexion ($p = 0.001$), a better TUG score ($p = 0.000$) and a better score for the 40 m walking test ($p = 0.000$) than those who were unable to climb the stairs. Those able to climb the stairs were also significantly younger than those unable to do so ($p = 0.002$) (Table III).

Table II. The effects of post-operative continuous passive motion (CPM) and active exercise compared with active exercise alone in patients who had undergone total knee arthroplasty.

	Preoperative		1 week post-operative		3 month post-operative	
	CPM and active exercise $n = 30$ Mean ± SD	Active exercise alone $n = 33$ Mean ± SD	CPM and active exercise $n = 30$ Mean ± SD	Active exercise alone $n = 33$ Mean ± SD	CPM and active exercise $n = 30$ Mean ± SD	Active exercise alone $n = 33$ Mean ± SD
Pain intensity (VAS 0–100)	52 ± 17	47 ± 19	40 ± 23*	40 ± 21	29 ± 22**	19 ± 15**
Knee circumference (cm)	40 ± 5	40 ± 4	43 ± 5**	44 ± 4**	41 ± 4**	41 ± 4**
Active flexion (°)	121 ± 14	127 ± 12	85 ± 13**	83 ± 16**	105 ± 18**	109 ± 14**
Passive flexion (°)	125 ± 14	131 ± 13	87 ± 11**	85 ± 16**	108 ± 18**	112 ± 14**
Active extension (°)	−3 ± 6	−4 ± 6	−8 ± 4**	−11 ± 6**	−4 ± 4	−7 ± 6*
Passive extension (°)	−2 ± 7	−2 ± 6	−7 ± 5**	−10 ± 6**	−2 ± 4	−5 ± 6*
Time Up and Go (sec)	12 ± 4	13 ± 6			11 ± 5	12 ± 6
40 m walking test (sec)	44 ± 39	41 ± 16			36 ± 12	40 ± 17
Stair climbing up and down (sec)	13 ± 5	14 ± 5			14 ± 9	12 ± 2
	($n = 21$)	($n = 19$)			($n = 13$)	($n = 15$)

Statistical significant within group differences compared with preoperative scores, p values at 5% level *, at 1% level **.

Table III. Characteristics of those able (copers) and those unable (non-copers) to perform the timed stair-climbing test before total knee arthroplasty and three months afterwards.

	Pre operative		After 3 months	
	Copers $n=40$	Non-copers $n=23$	Copers $n=28$	Non-copers $n=35$
Age	66 ± 9**	74 ± 10	65 ± 9**	73 ± 10
Active flexion (°)	127 ± 11*	119 ± 15	114 ± 12**	101 ± 16
Pain intensity (VAS 0–100)	47 ± 19	54 ± 16	18 ± 17*	28 ± 19
Time Up and Go (sec)	10 ± 3**	16 ± 6	9 ± 2**	14 ± 6
40 m walking test (sec)	32 ± 7**	50 ± 22	30 ± 5**	45 ± 17

Differences between groups, *p value ≤ 0.05, **p-value ≤ 0.01.

Discussion

CPM had no additional effect compared with active exercises alone on knee ROM, pain or walking ability at one week or three months after TKA. At three months, both groups had a statistically significant reduction in pain intensity compared with baseline, and the ability to rise from and sit down in a chair and walk on a flat surface was returned to pre-operative status. Knee ROM at three months was still reduced compared to baseline, and a smaller number of patients were able to climb stairs.

At the beginning of the study we posed the question of whether use of CPM would be more painful for the patient in the first post-operative phase because movement of the knee was frequent, continuous and had a large range of motion. However, we found that this was not the case. Others have found that the use of CPM resulted in less pain, and have suggested that this may be related to reduced swelling in the joint, as the continuous movement may empty the joint of blood and fluid [12,21,22]. We found a significant pain reduction, but an increased knee circumference at one week both in the CPM group and in the controls. This indicates that the use of CPM did not reduce swelling. Our finding of a considerable reduction in pain together with an increase in the circumference of the knee indicates that pain intensity is not closely associated with swelling. Since pain alleviation is a major therapeutic aim, the question is whether the statistically significant pain reduction has any clinical relevance. In our patients the average reduction in pain intensity between baseline and three months was almost 50% for the group as a whole, and a reduction in this magnitude is obviously clinically relevant.

One of the reasons for using CPM is to increase the knee ROM. We found no difference in ROM at one week between the control group and the CPM group, which indicates that CPM does not provide an additional benefit in the short term. A meta-analysis including four studies found a significantly increased active knee flexion of 4° in the CPM group after two weeks [5]. We believe this has marginal clinical relevance. Another important issue is that this meta-analysis has not been able to show benefits of CPM on knee ROM in the longer term. Thus when the findings of the various studies are taken together, CPM does not seem to provide an additional effect of clinical relevance above active physiotherapy exercises.

The group as a whole had recovered their baseline values on TUG and 40 m walking distance at three months. The knee ROM was significantly increased at three months compared to the measures on discharge from hospital. This improvement may be due to the normal healing process of the structures surrounding the joint. It seems probable that the knee prosthesis makes it easier to move the joint. Thus it is cause for concern that after three months the patients had still not achieved the same knee ROM as at baseline. The patients had followed an exercise programme after discharge from hospital, but this was not standardized and we do not know how conscientious they were at practising the exercises.

As mentioned above, the reason for focusing on treatment that improves joint mobility is that this might contribute to significantly improved walking ability. However, we found no associations between joint mobility and time used to rise from or sit down in a chair, walk on a flat surface or climb stairs. This indicates that joint mobility has little influence on walking speed. On the other hand, we found that a number of patients had difficulty in performing the stairs test under the conditions that we set. The test results showed great variation, and those who were unable to climb the stairs also scored considerably lower in all the other outcome variables, including flexion ROM. However, the results also showed that the flexion ROM for those unable to climb stairs at baseline was relatively similar to the average flexion range of motion of those able to climb stairs at three months. This indicates that there are other factors that might have an influence on the ability to climb stairs. These factors could be muscular strength, balance, motivation and level of anxiety.

Since the focus of the treatment was on improving mobility, ROM was the primary outcome variable measured in this study. Like others, we used a goniometer to measure ROM. It might be difficult to obtain reliable measurements with this instrument [24], and therefore the physiotherapists practised using the instrument to measure before the start of the study. The variance between the physiotherapists was satisfactory with an average difference of 3°, indicating satisfactory measurement reliability in this study. The TUG is a well-documented test that has mainly been used for frail elderly patients with balance problems [19]. The TKA patients took an average of 12 sec to complete the test, both at baseline and at three months. Since this is considered to be within the normal range, it produced a ceiling effect, which indicates that the TUG was not challenging enough to measure outcome in our patient group.

The external validity of the present study was good. The patients were recruited consecutively at a local hospital, and only three declined the invitation to participate. This indicates that there is little probability that the material was biased. The existence of a type 2 error is also unlikely as our material consisted of 63 patients, which is higher than the requisite sample number. Thus we believe that our results can be extrapolated to other patients who follow an exercise programme after TKA.

Conclusion

In conclusion, the present study showed that CPM as an adjunct to active exercises did not have any additional beneficial effects on pain, knee ROM, or walking ability compared with active exercises alone neither at one week nor at three months after TKA. The groups had not recovered their preoperative ROM three months after surgery, and a larger number of patients were unable to climb stairs compared with the number who could do this prior to surgery. No association was found between range of motion and walking ability.

Implications

The present study, conducted on a typical knee arthroplasty population, demonstrated that continuous passive motion did not show any additional effect above active exercises on pain and knee range of motion in the immediate postoperative period. These findings may lead to implications in clinical practice and question the use of continuous passive motion as a set procedure after total knee arthroplasty. It would in further research also seem important to evaluate the effects of post-operative exercises as such on range of motion and pain. In this study more patients were unable to climb stairs after three months than before surgery. These finding highlight the need for further research into the actual functional recovery after TKA and the effects of different physiotherapy approaches in this recovery process.

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