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Continuous Passive Motion after Knee Arthroscopy

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CONTINUOUS PASSIVE MOTION AFTER KNEE ARTHROSCOPY

by

Lisa Bauman

A Thesis
Submitted to the
Faculty of The Graduate College
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requirements for the
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CONTINUOUS PASSIVE MOTION AFTER KNEE ARTHROSCOPY

Lisa Bauman, M.A.
Western Michigan University, 1989

The purpose of the study was to investigate the effect of continuous passive motion (CPM) after arthroscopy. A CPM machine was used one hour following knee surgery. Statistical analysis was performed to determine differences in knee range of motion (ROM), strength and circumference, at time intervals preoperatively, one, seven, and twenty-eight days following surgery. The analysis of variance revealed no significant difference between the CPM and control groups for any parameter. A significant interaction effect between treatment and time was demonstrated one day after surgery for extension, joint line circumference, and mid-thigh circumference; and 28 days after surgery for the latter. Based on the results of this study, CPM decreased joint line and mid-thigh edema with resultant increased extension one day after knee arthroscopy. CPM had no effect on postoperative days 7 and 28. CPM did not influence strength, but may have prevented decreased mid-thigh girth, 28 days postoperatively.
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I am most indebted to the subjects who consented to be studied. Finally, thanks to my husband Bill, for his love, support, and child care, especially during the final weeks of thesis preparation.

Lisa Bauman
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Continuous passive motion after knee arthroscopy

Bauman, Lisa Jane, M.A.
Western Michigan University, 1989
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CHAPTER I

INTRODUCTION

Over the past decade, the use of arthroscopic surgery has increased dramatically. Research has supported many of the reasons for such an increase. In 1978, Dandy reported that patients who had undergone closed partial meniscectomies spent less time in the hospital and less time off work than those who had open procedures. Hamberg, Gillquist, and Lysholm (1984) lent credence to these findings. While studying partial versus total meniscectomies by open versus arthroscopic procedures, Hamberg et al. found that the arthroscopic partial meniscectomy group had taken the least amount of sick leave, the shortest operating time, and the smoothest postoperative course. Pettrone (1982) further validated these conclusions, as well as additional parameters of study. Pettrone demonstrated a decreased hospital stay (zero days versus four days), decreased cost ($1189.00 versus $1674.00), less time to reach 120 degrees flexion (10.4 days versus 42.8 days), less time away from sports (23.8 days versus 60 days), and less time spent on crutches (7.4 days versus 22.3 days) for the arthroscopic meniscectomy patient, compared with the
arthrotomy patient. Lysholm and Gillquist (1983) also revealed a shorter time away from sports, two to three weeks compared with two to three months, for athletes who had arthroscopies rather than open procedures. They believed that this was due to lessened quadriceps inhibition from the surgical procedure, which provided faster increases in isokinetic strength. Finally, Parisien (1988) reported on the use of arthroscopy to resect adhesions sustained after open procedures. Of 21 patients, 17 had good or excellent outcomes (no pain or functional limitation, near full range of motion), three had fair outcomes, and only one had no improvement.

Along with the increase in arthroscopies performed, has come the burgeoning use of continuous passive motion (CPM) machines postoperatively. Currently in this author's geographical area, the most common use of CPM is following total knee arthroplasty. In many sports medicine practices elsewhere, however, CPM has gained acceptance as a rehabilitation tool following ligament repair and arthroscopy. This has occurred in spite of a dearth of widely published clinical research supporting such practice. There is a need, therefore, to evaluate the effects of using CPM after arthroscopic surgery.
Statement of the Problem

The purpose of this study was to determine the effect of the CPM machine on patients after undergoing transarthroscopic surgery (TAS) to the knee.

Need for the Study

The importance of this study was the use of the CPM machine after arthroscopy. CPM machine use was widely accepted after total knee arthroplasties, (TKA) but had not been applied after TAS performed in the geographic area of the study. The study was expected to determine a need for change in patient management after TAS.

Delimitations

Twenty subjects were studied, aged 17-64 years. Each person had TAS performed on one knee as an outpatient at Butterworth Hospital in Grand Rapids, Michigan, by one of two physicians. The procedures performed were meniscectomies, plica removals, removal of loose bodies, and patellar shaving. Subjects had not previously had knee surgery, and the onset of injury ranged from two months to one year prior to TAS. A Cybex II was used for strength analysis, and a hand-held goniometer was used for range of motion (ROM)
measurements. A Danniflex CPM machine was used in the recovery room.

Limitations

The primary limitation of this study dealt with controlling the subjects' activities at home. Subjects were given exercises to perform, and instructions regarding crutch, ice, and ace wrap use, but may have had different attitudes toward following those directions. Another limitation was the subjects' pain tolerance. This may have affected their home exercise program adherence, and their performance on both the Cybex maximal strength test and ROM measurement. Finally, since a subject pool for random sampling was not available, an opportunistic sample was studied.

Assumptions

This study made two primary assumptions. First, the study assumed that the investigator measured the parameters according to the chosen procedures, and that instructions were given to each subject as directed. Secondly, it was assumed that all subjects followed their home instructions as directed.
Hypotheses

The study hypothesized that:

1. Subjects using CPM will have more ROM after surgery than subjects without CPM.

2. Subjects using CPM will have decreased edema, as shown by smaller circumferential measurements Days 1 and 7 after surgery, than subjects without CPM.

3. Subjects using CPM will perform better on a strength test than subjects without CPM.

4. Subjects using CPM will take less pain medication postoperatively than subjects without CPM.

5. Subjects using CPM will use crutches for a shorter period of time after surgery than subjects without CPM.

Definition of Terms

The following terms were defined as used in this study.

1. Continuous Passive Motion (CPM) machine: A motorized machine to which the leg is strapped. The machine passively flexes and extends the knee according to a programmed angle, rate of speed, and length of time.

2. Cybex II: The trade name of an isokinetic machine, it is used for measuring strength, and has a
lever arm which moves at a specified rate of speed. In this study, force applied to the moving lever arm by the leg was measured in foot pounds by a computer.


5. Range of Motion (ROM): In this study the flexion and extension of the knee, measured in degrees by a protractor-like device called a goniometer.

6. Total Knee Arthroplasty (TKA): An open surgery in which a prosthesis is placed in the knee, replacing the ends of the femur and tibia (thigh and leg bone).

7. Transarthroscopic Surgery (TAS): Microscopic closed surgery in which three incisions are made about the knee. Tubes are inserted into the incisions for viewing, drainage, and as a passageway for instruments to surgically manipulate tissues. It is an alternative to cutting open the knee for surgical procedures.
CHAPTER II

REVIEW OF LITERATURE

Immobilization

Extensive research has delineated the numerous changes which occur after limb immobilization. In muscle, decline has been demonstrated in; (a) the fractional rate of protein synthesis, (b) the wet weight, and (c) the state III respiration of subsarcolemmal mitochondria following immobilization (Booth & Seider, 1979; Kreiger, Tate, McMillin-Wood, & Booth, 1980; and Tucker, Seider, & Booth, 1981). Ligament dry weight and total collagen mass were also decreased after immobilization (Klein, Player, Heiple, Bahniuk, and Goldberg, 1982). Cartilage changes after immobilization have included weakened subchondral plates, fibrillations, irregular fiber arrangement, abnormal peripheral proliferation, and enchondral ossification (Hall, 1963; Langenskiold, Michelsson, & Videman, 1979; Michelsson & Riska, 1979; Steinberg & Trueta, 1981; and Videman, 1982). Bone was also affected by immobilization, with loss of mineral content, increased resorption rate, trabecular thinning, osteoporosis, and subcortical cysts occurring (Cann, Genant, & Young,
1980; Enneking & Horowitz, 1972; Klein et al., 1982; Steinberg & Trueta, 1981; and Videman, 1982).

Other research has demonstrated the reversibility of immobilization effects with activities of daily living and exercise (Palmoski & Brandt, 1981; and Tucker et al., 1981). Currently, the use of continuous passive motion (CPM) has been scrutinized as a way of possibly preventing the effects of immobilization.

**CPM - Animal Studies**

R.B. Salter seems to be the forefather of CPM research, although the concept of CPM and its first equipment have existed since the early 1900's. The bulk of Salter's work used rabbits as research subjects. In this study (Salter et al., 1980), CPM's effect on the healing of full thickness defects in articular cartilage was determined by gross examination and light microscopy. Defects one millimeter in diameter were made in the patellar groove, the anterior and middle parts of the medial femoral condyle, and the middle part of the lateral femoral condyle of the right hind knee of rabbits. The rabbits were then divided into three groups and treated as follows. The first group's operated limbs were immobilized in casts. The second group of rabbits was allowed to be active in cages as
desired. The third group of rabbits was placed on CPM. The unoperated left hind knees were used as control joints. The immobilized animals were sacrificed at one, two, three, and ten week intervals; the others were sacrificed at one, two, three, and four weeks. The following results were noted. Range of motion (ROM) of the immobilized group was 70-140 degrees at three weeks, with only a few degrees of motion present at 10 weeks. In the active group, ROM was limited by pain after the first week, but near normal after two weeks. ROM was normal in the CPM group at weeks one, two, three, and four. Intraarticular adhesions did not occur in the active or CPM groups, but appeared after three weeks in the immobilized group, and were extensive by 10 weeks. When healing of the defects was determined, it was found that in the immobilized group at three weeks, 85% of the defects were healing by fibrous tissue, whereas 15% were healing by the desired hyaline articular cartilage. At 10 weeks the condylar defects were covered by fibrous tissue adhesions whereas the patellar groove defects were filled with fibrous tissue (40%) or hyaline articular cartilage (60%). Healing of the active group's defects at three weeks showed 9% healing with hyaline cartilage, which dropped to 2% at four weeks. Healing of the CPM group's defects at week three was by
cartilage in 52% of the cases, which increased to 55% at four weeks. Thus Salter et al. (1980) demonstrated that CPM increased both the rate and completeness of healing of the articular cartilage defects when compared with an immobilized or intermittently active group.

A one year follow-up study to the above was also performed (Salter, Minster, Clements, Bogoch, & Bell, 1982). The immobilized group was casted for three weeks, then had full activity in rabbit runs eight feet long. The active group had one year of caged activity, and the third group received CPM for one week, followed by 51 weeks in the rabbit runs. Gross results showed that over half of the immobilized group lacked the last 10 degrees of extension, whereas the active and CPM groups had full ROM. In addition, the immobilized group demonstrated more osteophyte formation. While half of its defects were filled in, the other half were visible as depressions. The active group had 20% of the defects show up as depressions, whereas the CPM group had no visible depressions, and in 20% of the animals the defects were invisible. Histological inspection revealed that the CPM group formed a durable repair tissue with improved structural integrity, higher percentage of hyaline cartilage, and fewer degenerative changes than either the active or immobilized groups.
The superiority of the CPM healing was thus maintained at one year.

More recent studies by O'Driscoll, Keeley, & Salter (1986) have revealed similar findings. Larger full thickness defects (5x10 mm) were made in the patellar groove and medial femoral condyle of rabbits. The animals were either immobilized, allowed caged activity, or placed on CPM for two to four weeks. The CPM groups revealed restored groove contours, and significantly more formation of normal articular hyaline cartilage when examined by gross, histologic, histochemical, and biochemical methods. A one year follow-up report (O'Driscoll, Keeley, & Salter, 1988) demonstrated that the cartilage in the CPM groups remained superior and more durable than that of the other groups.

Optimal time of CPM was researched by Shimizu, Videman, Shimazaki, and Mooney (1987). Full thickness defects were formed by drilling into rabbit knees. The animals were then placed into one of the following six groups for one week: (a) CPM 24 hours daily; (b) CPM eight hours and immobilization (Imm) 16 hours daily; (c) CPM two hours and Imm 22 hours daily; (d) Imm 24 hours daily; (e) caged activity; or (f) Imm one week, then CPM 24 hours daily for one week. The groups with eight and twenty four hours of daily CPM demonstrated
significantly better repair than all other groups, thus optimal CPM time was eight hours or more.

O'Driscoll and Salter (1984) examined the influence of CPM on neochondrogenesis. In this experiment a periosteal graft was taken from the medial proximal tibia of each hind limb of 30 rabbits, and transplanted as a free body into the intercondylar notch of the same knee joint. A long cast was placed on one hind limb flexed to 40 degrees, the other limb was moved by CPM from 40 to 110 degrees at 1.5 cycles/minute. The animals were sacrificed at varying intervals, and examined grossly and histologically. The following results were noted. Grossly after one week, the grafts in each group appeared the same. After 14 to 17 days, the grafts in the CPM group were smooth, round, and glossy, resembling articular cartilage, whereas the grafts in the immobilized group were smaller, softer, and adhesions were present. After 21 days, the CPM grafts had the appearance of normal articular cartilage, and were contoured to their opposing articulating femoral condyles. Few of the immobilized group's grafts resembled cartilage; some were soft and others bone-hard. The above results were also demonstrated at 28 days. Histologically, cell proliferation was demonstrated after seven days; the CPM grafts had
cellular differentiation at 11 days, hyaline cartilage resemblance at 17 days, and normal cartilage cells at 21 days. Hyaline cartilage was the predominant tissue in 59% of the CPM grafts, and only 8% of the grafts in immobilized knees. This study was deemed clinically relevant toward the development of a method of biological (versus prosthetic) joint resurfacing.

CPM has been demonstrated to have beneficial effects on tissues other than cartilage. Salter and Ogilvie-Harris (cited in Cooper, 1979) studied CPM's effect on the healing of intraarticular fractures, citing the poor healing of the articular cartilage defect as a factor in the development of degenerative arthritis. Rabbits' limbs were fractured by hammering a scalpel through the medial femoral condyle in the sagittal plane, across the epiphysis, and extending into the metaphysis. They were fixated with an AO compression screw. The rabbits were then assigned to one of three groups. In group one, the knee was immobilized in plaster, flexed to 135 degrees. In group two, caged activity was allowed, representing early active motion. In group three, the knee was placed on CPM which moved from 20 to 100 degrees, at 1.5 cycles/minute. The animals were then sacrificed at one, two, three, and four weeks. The knees were examined grossly and
histologically with the following results. After four weeks, gross appearance of the immobilized group revealed severe loss of motion with condylar adhesions, pannus, and a thickened synovium. The fracture line was visible as a gap of white scar. The caged activity group showed normal ROM, with nonarticular adhesions, and in 80% of the limbs the articular surface was repaired with smooth shiny tissue. Histologic examination of the immobilized group demonstrated fibrous tissue present in the defect in 40% of the knees, with adhesions and degenerative cartilage changes also present. In the caged activity group 30% had fibrous tissue in the cartilage defects, 20% were being repaired with hyaline cartilage, and 50% had not healed. The CPM group's defects were being repaired by hyaline cartilage in 80% of the animals.

For the long term studies of Salter and Ogilvie-Harris (cited in Cooper, 1979) the same groups applied. The period of immobilization and CPM was either one or three weeks, and the rabbits were sacrificed at six months. Results were similar to the above findings, and reported as follows. Gross inspection of the immobilized group showed over half of the knees had decreased joint motion, and 60% of the animals had a gap in the cartilage. Thirty percent of the caged activity
group had mild loss of joint motion, and 20% of the knees revealed intercondylar adhesions. Half of the cartilage defects showed a persistent gap, 30% had a white scar line, and 20% had a smooth, shiny surface. The CPM group's knees had normal ROM, no adhesions, and 80% had a smooth shiny condylar surface. Histological examination showed that most of the immobilized group had degenerative arthritis on both condyles, with fibrillations, cleft formation, and disorientation of the collagen bundles. The defects' healing was by fibrous union. The group immobilized for three weeks was worse than that casted for one week. In the caged activity group, half of the knees had a gap in the cartilage, 30% were healed by hyaline cartilage, and 20% by fibrous tissue. Degenerative changes occurred at the fracture site, and there was collagen bundle disarray at the fracture gap edges. In the CPM group, collagen bundles were normally aligned, hyaline cartilage was present in 80% of the defects, and the fracture line was invisible in half of the knees. In summary, the CPM group demonstrated fewer adhesions (none), faster subchondral bone plate reconstitution, higher percentage of defect healing with hyaline cartilage, and less degenerative arthritis long term.

Salter, Bell, and Keeley (1981) offered the
following possible explanations for the protective
effect of CPM on articular cartilage in their research
on septic arthritis: (a) CPM prevented the formation of
synovial adhesions, and therefore pannus; (b) CPM
allowed an increased diffusion of synovial fluid
nutrients into the articular cartilage matrix; (c) CPM
enhanced the clearance of lysosomal enzymes and purulent
exudate; (d) CPM stimulated chondrocytes to increase
their synthesis of collagen and hexosamine; and (e) CPM
provided proprioceptive impulses to the moving joint,
blocking spinal level pain perception as in Wall's Gate
Theory (Salter et al., 1980).

Skyhar, Danzig, Hargens, and Akeson (1985) examined
the effect of CPM on nutrition of the anterior cruciate
ligament (ACL). Normally the ACL receives its nutrition
by diffusion from the synovial fluid, and its vascular
supply. With intraarticular repair of the ACL, however,
the transplanted patellar tendon is an avascular free
graft, its survival dependent upon synovial fluid.
Freshly killed rabbits were studied to simulate this
avascularity. Saline was injected intraarticularly,
after which the right knee was moved from 40 to 130
degrees flexion, at seven cycles/minute for one hour by
CPM. The left knee was immobilized at 90 degrees of
flexion. The ligaments were then sectioned and
prepared. A scintillation counter was used to determine nutrient uptake. Results showed that the immobilized ligaments had significantly higher uptake than those exposed to CPM. An interesting trend was also reported. Sulfate uptake was higher in the extraarticular tissues of the limb exposed to CPM, suggesting that CPM may facilitate metabolite transport out of the joint.

A similar study revealed slightly different results (Danzig et al., 1987). Sodium sulfate was injected into rabbit knees. The menisci and patellar tendons were then compared after one hour of CPM or immobilization. The menisci of each group had similar uptake except for the posterior one third of the lateral menisci. These portions had higher uptake in the immobilized group than the CPM group. Conversely, the patellar tendons of the CPM group had higher uptake than those of the immobilized group, supporting the trend reported in the above paragraph; namely CPM facilitated fluid transport out of the joint space to other tissue.

The effect of CPM on tendons has also been examined (Loitz, Zernicke, Vailas, Kody, & Meals, 1989). Steinmann pins were used to create articular injuries without surrounding tissue damage in the hindlimb ankles of rabbits. One ankle was then immobilized while the other was placed in a CPM device. After three weeks the
immobilized and CPM tibialis anterior tendons were compared with normal control tendons. While the control tendons were stronger than the CPM tendons, the CPM tendons had significantly greater linear and maximum stress, linear load, and ultimate strength than the immobilized tendons. In addition, there was no difference in the linear load and stress between CPM and control tendons. The authors concluded that CPM prevented the effects of short term immobilization of tendons stressed within the range of everyday activities.

In addition to its effects on joint tissues, CPM has been studied relative to joint effusion, which in hemophilia may cause synovial hypertrophy, adhesions, and joint stiffness, with ultimate degenerative arthritis. O'Driscoll, Kumar, and Salter (1983a) studied CPM's effect on hemarthrosis clearance from a synovial joint. Rabbits were again used as subjects. Both hind knees were injected with two milliliters of autologous anticoagulated erythrocytes, which had been labelled with indium-111-oxine, and reconstituted in normal saline. The left knees were casted, and the right were placed in CPM from 40 to 110 degrees of flexion. After 24 hours, gross findings were as follows: (a) CPM knees were without effusion and the
synovial fluid was less bloody than the casted knees; (b) after both the second and third days the synovial fluid of the CPM knees was clear, whereas the casted knees were still bloody; (c) after seven days the casted knees contained small amounts of blood in the synovium, the CPM knees were normal; and (d) scintillation scanning revealed that the clearance of the CPM knees' indium-111-oxine-labelled erythrocytes was more than twice that of the casted knees. Also, CPM reduced the synovial erythrocyte trapping more than in the immobilized knees. Both of these two findings suggest a reduced risk of degenerative arthritis secondary to hemarthrosis, due to clearance of the potentially destructive proteolytic enzymes.

In a related study, O'Driscoll, Kumar, and Salter (1983b) studied the effect of CPM on intraarticular pressure in the rabbit knee. Two milliliters of saline were injected into both knees of a rabbit, which was then placed on CPM from 40 to 110 degrees flexion at 1.5 cycles/minute. The measured intraarticular pressures during CPM followed a sinusoidal curve. The authors postulated that this curve revealed the "pumping" effect which facilitated clearance of the hemarthroses in the previous study. Also, after five minutes of CPM, the intraarticular pressures had decreased by 5-10 mm Hg,
probably from viscoelastic stretching of the capsule. A related study on the human knee by Pedowitz et al. (1989) revealed similar results. Capsular viscoelastic changes and/or synovial fluid volume changes with CPM use were reported. In addition, cyclic change in articular pressure was demonstrated with CPM.

**CPM - Human Studies**

Other CPM research has used human subjects. Burks, Daniel, and Losse (1984) studied CPM's effect on cadaver knees that had undergone three types of anterior cruciate ligament repairs, the Marshall-MacIntosh OTT, a patellar bone-tendon-tubercle bone graft (BTB), and a semitendinosus reconstruction. The knees were placed on a CPM from 20 to 70 degrees, at 10 cycles/minute for three days. An arthrometer measured both the intact and repaired ligaments, the latter measurement had to be within two millimeters of the former to be considered a successful repair. Results revealed that three of three BTB grafts failed. Six of eight semitendinosus grafts failed, while eight of nine OTT repairs were successful. The study was criticized by Seigel (Burks et al., 1984, p. 327), who believed that graft placement sites and tensions were wrong and caused the failures, rather than the CPM treatment. Losse (1986) later agreed that there
were problems with the study, and in a lecture stated that CPM was used with almost all of the ACL reconstructions performed.

Greene (1983) studied CPM's postoperative effect on pediatric knee and elbow problems. The CPM machine was applied at a speed of one revolution per 12.5 minutes for two to three weeks, 24 hours per day. After active range of motion (AROM) and strengthening began in physical therapy, CPM was used 18 hours per day until discharge from the hospital. Four hemophiliac patients were studied. Three had knee synovectomies, one had an elbow synovectomy. When compared to a similar group that had not used CPM, the following was revealed. None of the CPM group needed manipulation under general anesthesia, whereas the control group averaged one manipulation per patient. The average hospital stay for the CPM group was 39.8 days, versus 54.2 days for the control group. Transfusion requirements were also significantly less for the CPM group. Three months after surgery, the average ROM of the CPM group was 74 degrees flexion; it was 45 degrees for the control group. The CPM group had lost an average of 10 degrees ROM at a one year follow-up visit; the control group lost 32 degrees. Three other patients were studied who had long standing limitation of joint motion which
required surgery. The average joint motion before surgery, at completion of surgery, and at hospital discharge was 13.3, 43.3, and 56.7 degrees, respectively. These unique cases could not be compared with controls, but the authors believed that CPM was beneficial in achieving ROM and aiding rehabilitation.

A number of authors have reported on the use of CPM after total knee arthroplasty (TKA). Coutts et al. (1982) studied two groups of patients, comparable in age, sex, and arthritis type. The control group was immobilized in plaster reinforced compression bandages for three to four days, followed by free active motion. The CPM group had their knees placed on CPM through varying arcs of motion, never less than 30 degrees, for 20 out of 24 hours per day until discharged. Results revealed the average hospital stay of the CPM group was 12 days; it was 15 days for the control group. None of the CPM group required manipulation; it was performed on five of fourteen control group subjects. After 10 days, the average flexion of the control group was 67.8 degrees, compared with 100.6 degrees for the CPM group. Pain medication used by the CPM group was significantly lower than the control group. Thus the CPM group achieved ROM more quickly, and with less discomfort than the control group.
Another study with a greater subject population, 
(n = 142) revealed results similar to Coutts et al. 
(Brown, 1986). The CPM group had greater flexion after 
one week, was able to do a straight leg raise sooner, 
had more flexion at discharge, and a decreased length of 
hospitalization when compared with a control group. 
Goletz and Henry (1986) also reported fewer days 
hospitalization and fewer days to reach 90 degrees 
flexion for the CPM versus control groups. More wound 
healing complications were found in the CPM group. 
These were attributed to subjects having gained motion 
too quickly (90 degrees flexion five and six days after 
surgery). Therefore, a protocol was developed so that 
patients would reach 90 degrees flexion on the eighth to 
tenth day after surgery. The authors suggested setting 
extension at zero and flexion at 30 degrees for the 
first two days, then increasing flexion five degrees 
twice daily as tolerated. 

Other research has contradicted some of the above 
findings. In attempting to determine optimal CPM 
duration, groups were compared without CPM, with 10 
hours of CPM daily, and with 20 hours of CPM daily 
(Evans, 1986). No significant difference was 
demonstrated in any of the following parameters; 
narcotic use, non-narcotic pain reliever use, wound
complications, or days to discharge. However, the number of days to attain 90 degrees of flexion was significantly different. The control group average was 11.0 days; the 10 hour CPM group took 8.0 days; and the 20 hour CPM group average was 7.8 days. Romness and Rand (1988) also reported a significant difference in days to reach 90 degrees flexion. The CPM group averaged 7.7 days, while the control group averaged 10.3 days. However, there was no significant difference in length of hospitalization or range of motion after one year. Vince, Kelly, Beck, and Insall (1987) further reported a significant difference in days to reach 90 degrees flexion; 9.1 days for the CPM group and 13.8 days for the controls. Venograms were performed on each subject. Positive studies occurred in 45% of the CPM group and 75% of controls. However, no patients had symptomatic thrombophlebitis or positive lung scans. Lynch, Bourne, Rorabeck, Rankin, and Donald (1988) contradicted this finding. Positive venograms occurred 40% of the time in both control and CPM groups after TKA. Ritter, Gandolf, and Holston (1989) studied patients with simultaneous bilateral TKAs. There was no significant difference in motion of the knees, but there was significantly decreased swelling in the CPM group.

Several studies have sought to reveal optimal time
of CPM use after TKA. Nielsen, Rechnagel, and Nielsen (1988) compared a group using CPM two hours twice daily to a control group. No significant difference was found in range of motion or pain between the two groups. Time was chosen based on an earlier study by Basso and Knapp (1987). Two groups of CPM users were compared. Group 1 used the CPM at least 20 hours per day. Group 2 used the CPM a maximum of five hours daily. Measurements were recorded on days three and six postoperatively. No significant difference was found in edema, pain, length of hospital stay or knee flexion. However, on day six, Group 2 had significantly more knee extension than Group 1. An incidental finding of the study was a significant negative correlation between the number of physical therapy treatments received in the first six postoperative days, and the length of hospital stay. Gose (1987) reported on a retrospective study which compared subjects who received one hour sessions of CPM three times a day with a control group. While there was no significant difference in knee range of motion at discharge, the CPM group demonstrated a significantly lower frequency of complications and decreased length of postoperative hospital stay. Finally, Laupattarakasem (1988) presented a three day CPM protocol of five hour cycles with one hour intermissions. Near normal knee
motion was reported after three days, and was maintained at a six month follow-up.

James and Wade (1987) reported on a complication of CPM use. One case of lateral popliteal nerve palsy was summarized. The patient reported pain 36 hours after surgery. This was due to improper padding placement behind the knee, and CPM providers were cautioned to ensure correct placement.

In addition to the above research cited, CPM was also mentioned as a part of the postoperative rehabilitation regime by Perry, Evans, Rice, Fogarty, and Burdge (1984) after lateral tibial plateau fracture fixation. Noyes, Mangine, and Barber (1987) developed a CPM protocol for the postoperative open and arthroscopic ACL repair patient. Eilers (1986) wrote of using CPM "routinely for both total knee and total hip replacements" (p. 2), as well as following arthroscopy, particularly on an outpatient basis. Losse (1986) stated in a lecture that CPM was used after ACL repair and also in the recovery room following most arthroscopic surgeries. This reduced the need for pain medication in recovery from 33% to 12%. It was from this lecture that the idea for this research was formed.
CHAPTER III

EXPERIMENTAL PROCEDURES

The purpose of this study was to determine the effects of continuous passive motion (CPM) after arthroscopic knee surgery. The procedures utilized in the investigation are found under the following headings; (a) Subjects, (b) Instrumentation, (c) Pretest, (d) Treatment, (e) Posttest, and (f) Statistical Design.

Subjects

Subjects in this study were men and women aged 17 to 64 years, who had outpatient arthroscopy at Butterworth Hospital in Grand Rapids, Michigan. None had prior knee surgery on the studied knee, and their knees had been injured no longer than one year prior to surgery.

Because a pool of subjects meeting the above criteria was not readily available, individual patients who after initial evaluation were determined to have met the criteria, and who agreed to participate in the study by signing an informed consent document (see Appendix A), were placed in one of two groups. The first person
who met the criteria was assigned to the CPM group. The second person who met the criteria was assigned to the control group. This procedure was continued, as subjects became available, and with treatment ongoing, until each group contained 10 subjects, five males and five females.

Instrumentation

The Cybex II isokinetic machine with data reduction computer was used to measure strength. The machine was calibrated monthly throughout the study to ensure accuracy of output. A metal 180 degree goniometer was used for range of motion measurements.

Procedures

Pretest

The initial evaluation occurred one to two hours prior to arthroscopic surgery. Each subject was instructed in crutch gait, with weight bearing as tolerated on the involved limb. Aluminum axillary crutches were fitted and issued as necessary. Knee flexion was measured prone by aligning the goniometer with the subjects' greater trochanter, lateral tibial condyle, and lateral malleolus. Knee extension was measured supine, with the subjects' heel placed on a two
inch pad. Circumferential measurements were recorded in centimeters, at the midpatella, suprapatella, and 5 and 15 centimeters proximal to the superior border of the patella. The subject was situated on the Cybex II as follows. The shin pad was placed just proximal to the malleoli, and below the bulk of the calf. The dynamometer axis was placed even with the lateral femoral condyle. The subject was stabilized by the shin, thigh, and pelvic straps. The subject was allowed a three to five submaximal repetition warm-up at 180 degrees/second to become accustomed to the machine. Four maximal full arc repetitions at the same speed were then recorded by the computer, first on the uninvolved leg, then on the leg which was to have arthroscopic surgery. Verbal encouragement was given by the investigator. Finally, each subject was instructed in supine straight leg raises and sitting full arc quad exercises, and practiced until demonstrated correctly. Proper use of ice postoperatively was discussed.

Treatment

All subjects underwent transarthroscopic surgery, under general anesthesia. Marcane, a long acting local anesthetic, was also used. Subjects in the CPM group were placed on the Danniflex CPM machine in the recovery
room immediately following surgery, for 55 to 60 minutes. The range of motion was set at zero extension, and 75 to 80 degrees flexion, per patient tolerance. The machine moved at two cycles/minute. Additionally, the time of surgery and amount of pain medication required in recovery were recorded. Each subject was also given a prescription for 30 Tylenol #3 tablets to take at home as necessary for pain, two tablets every four hours.

The day after surgery, ROM and circumferential measurements were recorded as stated in the pretest. In addition, subjects were instructed in the proper use of heat and cold following surgery, and their exercises were reviewed. One week after surgery, subjects again reviewed their exercises and the proper postoperative use of heat and cold with the investigator.

**Posttest**

Range of motion, circumference, and strength measurements were recorded both one week and one month after surgery, as described in the pretest. In addition, use of pain medication and crutches, exercise repetitions, and time off work were also recorded.
Statistical Design

To analyze range of motion, strength and circumference, the split-plot factorial analysis of variance (ANOVA) design was used (Kirk, 1968). The independent variables were use of CPM and time. The dependent variables analyzed by this design were range of motion, strength, and circumference. The computer program used to run the ANOVAs was BMPD 2V. Descriptive statistics were used to analyze days of crutch and medication use.
CHAPTER IV

RESULTS AND DISCUSSION

This study investigated the effect of post arthroscopic continuous passive motion (CPM) on knee range of motion (ROM), strength, and circumference. Results were described under the following subheadings; (a) Subject Demographic Data, (b) ROM, (c) Strength, (d) Circumference, and (e) Crutch and Medication Use. The Discussion section followed Results. The split-plot factorial analysis of variance (ANOVA) design was used to analyze the dependent variables ROM, strength, and circumference. The independent variables were treatment (CPM) and time.

Results

Subject Demographic Data

The average ages for subjects in the CPM group and control group were 35.56 years and 38.74 years respectively. In the CPM group three subjects had medial meniscectomy, one subject had lateral meniscectomy, two subjects had a plica removed, one had removal of loose bodies, and three had medial meniscectomy combined with loose body removal or
patellar shaving. In the control group, distribution by surgical procedure occurred as follows; (a) three medial meniscectomies, (b) four plica removals, and (c) three medial meniscectomies with combination loose body removal or patellar shaving. Tourniquet time for the CPM group was 17.3 minutes; it was 19.9 minutes for the control group.

ROM

**Extension**

The split-plot factorial ANOVA design was used to analyze the dependent variable extension ROM. The ANOVA summary table for extension ROM is presented in Table 1. The mean score for the control group was -3.00 degrees, and the mean score for the CPM group was -1.61 degrees. The analysis of variance revealed no significant difference between CPM and control groups in degrees of extension, $F(1, 10) = 1.76, p < .05$.

There was a significant difference within subjects over time, $F(3,30) = 41.69, p < .05$. The means of extension in degrees were; (a) Preoperative = -0.42, (b) postoperative Day 1 = -6.67, (c) postoperative Day 7 = -1.25, and (d) postoperative Day 28 = -0.42.
Table 1

Analysis of Variance Summary Table for Knee Extension

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Subjects (Subj.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPM (C)</td>
<td>22.63</td>
<td>1</td>
<td>22.63</td>
<td>1.76</td>
</tr>
<tr>
<td>Subj. w/groups</td>
<td>128.93</td>
<td>10</td>
<td>12.89</td>
<td></td>
</tr>
<tr>
<td>Within Subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time (T)</td>
<td>349.93</td>
<td>3</td>
<td>116.64</td>
<td>41.69*</td>
</tr>
<tr>
<td>CT</td>
<td>33.26</td>
<td>3</td>
<td>11.09</td>
<td>3.69*</td>
</tr>
<tr>
<td>T x Subj. w/groups</td>
<td>83.93</td>
<td>30</td>
<td>2.80</td>
<td></td>
</tr>
</tbody>
</table>

*  p < .05.

The interaction effect between treatments and time was also significant, F(3, 30) = 3.96, p < .05. Figure 1 revealed that the interaction effect occurred on postoperative Day 1. Mean extension for the CPM group was -5.00 degrees; it was -9.00 degrees for the control group. Means and standard deviations for the CPM and control groups are displayed in Table 2.
Figure 1. Mean Knee Extension over Time for the Control and CPM Groups

T1: Preoperative
T2: Postoperative Day 1
T3: Postoperative Day 7
T4: Postoperative Day 28
Table 2
Means and Standard Deviations of Extension ROM in Degrees

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Control</th>
<th>CPM</th>
<th>Marginal Means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Pre-op</td>
<td>0.00</td>
<td>0.00</td>
<td>-0.71</td>
</tr>
<tr>
<td>Post-op</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 1</td>
<td>-9.00</td>
<td>4.18</td>
<td>-5.00</td>
</tr>
<tr>
<td>Day 7</td>
<td>-2.00</td>
<td>2.74</td>
<td>-0.71</td>
</tr>
<tr>
<td>Day 28</td>
<td>-1.00</td>
<td>2.23</td>
<td>0.00</td>
</tr>
<tr>
<td>Marginal Means</td>
<td>(Treatments)</td>
<td>-3.00</td>
<td>-1.61</td>
</tr>
</tbody>
</table>

Flexion

The split-plot factorial ANOVA design was also used to analyze data with the dependent variable flexion ROM. The ANOVA summary table for flexion ROM is presented in Table 3. The analysis of variance indicated no
significant difference between CPM and control groups in
degrees of flexion, $F(1, 11) = 1.96$, $p < .05$. The mean
score for the control group was 109.17 degrees, and the
CPM group's mean score was 115.18 degrees.

Table 3

Analysis of Variance Summary Table for Knee Flexion

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>$F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Subjects (Subj.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPM (C)</td>
<td>467.08</td>
<td>1</td>
<td>467.08</td>
<td>1.96</td>
</tr>
<tr>
<td>Subj. w/groups</td>
<td>2626.19</td>
<td>11</td>
<td>238.74</td>
<td></td>
</tr>
<tr>
<td>Within Subj.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time (T)</td>
<td>11104.62</td>
<td>3</td>
<td>3701.54</td>
<td>31.27*</td>
</tr>
<tr>
<td>CT</td>
<td>181.55</td>
<td>3</td>
<td>3701.54</td>
<td>0.51</td>
</tr>
<tr>
<td>T x Subj. w/groups</td>
<td>3905.95</td>
<td>33</td>
<td>118.36</td>
<td></td>
</tr>
</tbody>
</table>

* $p < .05$.

There was a significant difference within subjects
over time, $F(3, 33) = 31.27$, $p < .05$. The means of
flexion in degrees were; (a) preoperative = 121.92, (b)
postoperative Day 1 = 88.46, (c) postoperative Day 7 =
113.08, and (d) postoperative Day 28 = 126.15.

There was no significant interaction effect between
treatments and time, $F(3, 33) = 0.51$, $p < .05$. Means
and standard deviations for the CPM and control groups.
are displayed in Table 4.

Table 4
Means and Standard Deviations of Flexion ROM in Degrees

<table>
<thead>
<tr>
<th>Time</th>
<th>Control Mean</th>
<th>Control SD</th>
<th>CPM Mean</th>
<th>CPM SD</th>
<th>Marginal Means (Times)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-op</td>
<td>120.83</td>
<td>10.68</td>
<td>122.86</td>
<td>6.36</td>
<td>121.92</td>
</tr>
<tr>
<td>Post-op</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 1</td>
<td>85.00</td>
<td>17.89</td>
<td>91.43</td>
<td>13.45</td>
<td>88.46</td>
</tr>
<tr>
<td>Day 7</td>
<td>106.67</td>
<td>16.02</td>
<td>118.57</td>
<td>14.06</td>
<td>113.08</td>
</tr>
<tr>
<td>Day 28</td>
<td>124.17</td>
<td>4.92</td>
<td>127.86</td>
<td>8.59</td>
<td>126.15</td>
</tr>
</tbody>
</table>

Marginal Means
(Treatments) 109.17 115.17 112.40

Strength

Extension

The split-plot factorial ANOVA design was used to analyze the dependent variable extension strength. The ANOVA summary table for extension strength is presented in Table 5. The mean score for the control group was 42.89% body weight, and the CPM group's mean score was 43.86% body weight. The analysis of variance
demonstrated no significant difference between CPM and control groups in extension strength, $F(1, 11) = .01$, $p < .05$.

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>$F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPM (C)</td>
<td>9.09</td>
<td>1</td>
<td>9.09</td>
<td>0.01</td>
</tr>
<tr>
<td>Subj. w/groups</td>
<td>10665.02</td>
<td>11</td>
<td>969.55</td>
<td></td>
</tr>
<tr>
<td>Within Subj.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time (T)</td>
<td>1161.41</td>
<td>2</td>
<td>580.70</td>
<td>6.68*</td>
</tr>
<tr>
<td>CT</td>
<td>15.25</td>
<td>2</td>
<td>7.63</td>
<td>0.09</td>
</tr>
<tr>
<td>T x Subj. w/groups</td>
<td>1911.41</td>
<td>22</td>
<td>86.88</td>
<td></td>
</tr>
</tbody>
</table>

* $p < .05$.

There was a significant difference within subjects over time, $F(2, 22) = 6.68$, $p < .05$. The means of extension strength, expressed in percentage of body weight were; (a) preoperative = 48.85, (b) postoperative Day 7 = 36.00, and (c) postoperative Day 28 = 45.38.

There was no significant interaction effect between treatments and time, $F(2, 22) = .09$, $p < .05$. Means and standard deviations for extension strength are displayed.
in Table 6.

### Table 6

**Means and Standard Deviations of Extension Strength Measured as a Percent of Body Weight**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Control</th>
<th>CPM</th>
<th>Marginal Means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Pre-op</td>
<td>49.17</td>
<td>14.74</td>
<td>48.57</td>
</tr>
<tr>
<td>Post-op</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 7</td>
<td>34.67</td>
<td>20.32</td>
<td>37.14</td>
</tr>
<tr>
<td>Day 28</td>
<td>44.83</td>
<td>13.62</td>
<td>45.86</td>
</tr>
<tr>
<td>Marginal Means (Treatments)</td>
<td>42.89</td>
<td></td>
<td>43.86</td>
</tr>
</tbody>
</table>

**Flexion**

The split-plot factorial ANOVA design was also used to analyze the dependent variable flexion strength. The ANOVA summary table for flexion strength is presented in Table 7. The mean score expressed in percent body weight, for the control group was 21.78, and the mean score for the CPM group was 28.05. The analysis of variance revealed no significant difference between CPM and control groups in flexion strength,
\( F(1, 11) = 0.71, \ p < 0.05. \)

**Table 7**

Analysis of Variance Summary Table for Flexion Strength

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Subjects (Subj.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPM (C)</td>
<td>381.01</td>
<td>1</td>
<td>381.01</td>
<td>0.71</td>
</tr>
<tr>
<td>Subj. w/groups</td>
<td>5866.73</td>
<td>11</td>
<td>533.34</td>
<td></td>
</tr>
<tr>
<td>Within Subjects</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time (T)</td>
<td>429.95</td>
<td>2</td>
<td>214.98</td>
<td>5.55*</td>
</tr>
<tr>
<td>CT</td>
<td>49.23</td>
<td>2</td>
<td>24.62</td>
<td>0.64</td>
</tr>
<tr>
<td>T x Subj. w/groups</td>
<td>851.79</td>
<td>22</td>
<td>38.72</td>
<td></td>
</tr>
</tbody>
</table>

* \( p < 0.05. \)

There was a significant difference within subjects over time, \( F(2, 22) = 5.55, \ p < 0.05. \) The means of flexion strength expressed in percentage of body weight were: (a) preoperative = 24.69, (b) postoperative Day 7 = 21.31, and (c) postoperative Day 28 = 29.46.

There was no significant interaction effect between treatments and time, \( F(2, 22) = 0.64, \ p < 0.05. \) Means and standard deviations for flexion strength are displayed in Table 8.
Table 8
Means and Standard Deviations of Flexion Strength Measured as a Percent of Body Weight

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Control</th>
<th>CPM</th>
<th>Marginal Means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Pre-op</td>
<td>19.67</td>
<td>10.29</td>
<td>29.00</td>
</tr>
<tr>
<td>Post-op</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 7</td>
<td>19.17</td>
<td>11.23</td>
<td>23.14</td>
</tr>
<tr>
<td>Day 28</td>
<td>26.50</td>
<td>10.64</td>
<td>32.00</td>
</tr>
<tr>
<td>Marginal Means (Treatments)</td>
<td>21.78</td>
<td>28.05</td>
<td>25.15</td>
</tr>
</tbody>
</table>

Joint Line

The split-plot factorial ANOVA design was used to analyze the dependent variable joint line circumference. The ANOVA summary table for joint line circumference is presented in Table 9. The mean score in centimeters for the control group was 39.75, and the mean score for the CPM group was 38.68. The analysis of variance indicated no significant difference between CPM and control groups in joint line circumference, $F(1, 11) = 0.47, p < .05$. 

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Table 9
Analysis of Variance Summary Table for Joint Line Circumference

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Subjects (Subj.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPM (C)</td>
<td>14.83</td>
<td>1</td>
<td>14.83</td>
<td>0.47</td>
</tr>
<tr>
<td>Subj. w/groups</td>
<td>350.48</td>
<td>11</td>
<td>31.86</td>
<td></td>
</tr>
<tr>
<td>Within Subj.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time (T)</td>
<td>33.10</td>
<td>3</td>
<td>11.04</td>
<td>28.95*</td>
</tr>
<tr>
<td>CT</td>
<td>4.10</td>
<td>3</td>
<td>1.37</td>
<td>3.59*</td>
</tr>
<tr>
<td>T x Subj. w/groups</td>
<td>12.57</td>
<td>33</td>
<td>0.38</td>
<td></td>
</tr>
</tbody>
</table>

* p < .05.

There was a significant difference within subjects over time, $F(3, 33) = 28.95, p < .05$. The means of joint line circumference, measured in centimeters were; (a) preoperative = 38.38, (b) postoperative Day 1 = 40.42, (c) postoperative Day 7 = 39.23, and (d) postoperative Day 28 = 38.65.

There was also a significant interaction effect between treatments and time, $F(3, 33) = 3.59, p < .05$. Figure 2 demonstrates that this occurred on postoperative Day 1. Mean joint line circumference for the control group was 41.50 cm; it was 39.50 cm for the
T1: Preoperative
T2: Postoperative Day 1
T3: Postoperative Day 7
T4: Postoperative Day 28

Figure 2. Mean Joint Line Circumference over Time for the Control and CPM Groups

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CPM group. Means and standard deviations for joint line circumference are displayed in Table 10.

Table 10
Means and Standard Deviations of Joint Line Circumference in Centimeters

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Control</th>
<th>CPM</th>
<th>Marginal Means</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Pre-op</td>
<td>38.92</td>
<td>3.75</td>
<td>37.93</td>
</tr>
<tr>
<td>Post-op</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 1</td>
<td>41.50</td>
<td>3.45</td>
<td>39.50</td>
</tr>
<tr>
<td>Day 7</td>
<td>39.50</td>
<td>3.36</td>
<td>39.00</td>
</tr>
<tr>
<td>Day 28</td>
<td>39.08</td>
<td>3.48</td>
<td>38.29</td>
</tr>
<tr>
<td>Marginal Means (Treatments)</td>
<td>39.75</td>
<td>38.67</td>
<td>39.17</td>
</tr>
</tbody>
</table>

Suprapatellar

The split-plot factorial ANOVA design was also used to analyze the dependent variable circumference measured at the superior border of the kneecap (suprapatella). The ANOVA summary table for suprapatellar circumference is presented in Table 11. The mean score in centimeters for the control group was 41.31; it was 40.30 for the
CPM group. The analysis of variance demonstrated no significant difference between the CPM and control groups in suprapatellar circumference, $F(1, 11) = 0.15$, $p < .05$.

| Table 11 |
| Analysis of Variance Summary Table for Suprapatellar Circumference |
| Source | SS | df | MS | F |
| Between Subjects (Subj.) | | | | |
| CPM (C) | 13.15 | 1 | 13.15 | 0.15 |
| Subj. w/groups | 971.58 | 11 | 88.32 | |
| Within Subj. | | | | |
| Time (T) | 39.92 | 3 | 13.30 | 20.85* |
| CT | 1.98 | 3 | 0.66 | 1.03 |
| T x Subj. w/groups | 21.06 | 33 | 0.64 | |

* $p < .05$.

There was a significant difference within subjects over time, $F(3, 33) = 20.85$, $p < .05$. The means of suprapatellar circumference, measured in centimeters, were: (a) preoperative = 40.00, (b) postoperative Day 1 = 42.23, (c) postoperative Day 7 = 40.65, and (d) postoperative Day 28 = 40.19.

There was no significant interaction effect between
treatments and time, $F(3, 33) = 1.03, p < .05$. Means and standard deviations for suprapatellar circumference are displayed in Table 12.

Table 12

Means and Standard Deviations of Suprapatellar Circumference in Centimeters

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Control</th>
<th>CPM Marginal Means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Pre-op</td>
<td>40.67</td>
<td>5.36</td>
</tr>
<tr>
<td>Post-op</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 1</td>
<td>42.92</td>
<td>5.09</td>
</tr>
<tr>
<td>Day 7</td>
<td>40.83</td>
<td>5.30</td>
</tr>
<tr>
<td>Day 28</td>
<td>40.83</td>
<td>5.07</td>
</tr>
<tr>
<td>Marginal Means</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Treatments)</td>
<td>41.31</td>
<td>40.30</td>
</tr>
</tbody>
</table>

**Lower Thigh**

The split-plot factorial ANOVA design was further used to analyze the dependent variable of circumference measured five centimeters proximal to the superior border of the patella (lower thigh). This ANOVA summary table is presented in Table 13. The mean score in
centimeters for the control group was 42.09; it was 41.97 for the CPM group. The analysis of variance indicated no significant difference in lower thigh circumference between CPM and control groups $F(1, 6) = 0.00, p < .05$.

Table 13
Analysis of Variance Summary Table for Lower Thigh Circumference

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>$F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Subjects (Subj.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPM (C)</td>
<td>.012</td>
<td>1</td>
<td>0.12</td>
<td>0.00</td>
</tr>
<tr>
<td>Subj. w/groups</td>
<td>648.47</td>
<td>6</td>
<td>108.18</td>
<td></td>
</tr>
<tr>
<td>Within Subj.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time (T)</td>
<td>11.78</td>
<td>3</td>
<td>3.93</td>
<td>6.88*</td>
</tr>
<tr>
<td>CT</td>
<td>0.81</td>
<td>3</td>
<td>0.27</td>
<td>0.47</td>
</tr>
<tr>
<td>T x Subj. w/groups</td>
<td>10.28</td>
<td>18</td>
<td>0.57</td>
<td></td>
</tr>
</tbody>
</table>

* $p < .05$.

There was a significant difference within subjects over time, $F(3, 18) = 6.88, p < .05$. The means of lower thigh circumference, measured in centimeters were; (a) preoperative = 41.62, (b) postoperative Day 1 = 43.06, (c) postoperative Day 7 = 41.88, and (d) postoperative Day 28 = 41.56.
There was no significant interaction effect between treatments and time, $F(3, 18) = 0.47, p < .05$. The means and standard deviations of circumference five centimeters proximal to the superior border of the patella are displayed in Table 14.

### Table 14
Means and Standard Deviations of Lower Thigh Circumference in Centimeters

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Control</th>
<th>CPM</th>
<th>Marginal Means</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Pre-op</td>
<td>41.50</td>
<td>6.61</td>
<td>41.75</td>
</tr>
<tr>
<td>Post-op</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 1</td>
<td>43.25</td>
<td>6.13</td>
<td>42.88</td>
</tr>
<tr>
<td>Day 7</td>
<td>42.12</td>
<td>6.46</td>
<td>41.62</td>
</tr>
<tr>
<td>Day 28</td>
<td>41.50</td>
<td>6.07</td>
<td>41.62</td>
</tr>
<tr>
<td>Marginal Means (Treatments)</td>
<td>42.09</td>
<td>41.97</td>
<td>42.03</td>
</tr>
</tbody>
</table>

**Mid-Thigh**

Finally, the split-plot factorial ANOVA design was used to analyze the dependent variable circumference measured 15 centimeters proximal to the superior border...
of the patella (mid-thigh). This ANOVA summary table is presented in Table 15. The mean score in centimeters for the control group was 50.21; it was 52.17 for the CPM group. The analysis of variance revealed no significant difference between control and CPM groups, $F(1, 4) = 0.10$, $p < .05$.

Table 15
Analysis of Variance Summary Table for Mid-Thigh Circumference

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Subjects (Subj.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPM (C)</td>
<td>23.01</td>
<td>1</td>
<td>23.01</td>
<td>0.10</td>
</tr>
<tr>
<td>Subj. w/groups</td>
<td>877.96</td>
<td>4</td>
<td>219.49</td>
<td></td>
</tr>
<tr>
<td>Within Subj.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time (T)</td>
<td>9.95</td>
<td>3</td>
<td>3.32</td>
<td>4.03*</td>
</tr>
<tr>
<td>CT</td>
<td>14.61</td>
<td>3</td>
<td>4.87</td>
<td>5.92*</td>
</tr>
<tr>
<td>T x Subj. w/groups</td>
<td>9.88</td>
<td>12</td>
<td>0.82</td>
<td></td>
</tr>
</tbody>
</table>

* $p < .05$

There was a significant difference within subjects over time, $F(3, 12) = 4.03$, $p < .05$. The means of mid-thigh circumference measured in centimeters were; (a) preoperative = 50.92, (b) postoperative Day 1 = 52.08, (c) postoperative Day 7 = 51.42, and (d) postoperative
Day 28 = 50.33.

There was also a significant interaction effect between treatments and time, $F(3, 12) = 5.92, p < .05$. Figure 3 reveals that this occurred on postoperative Day 1. The control group mean was 52.33 centimeters (cm), a mean increase of 2.83 cm from the preoperative mean. The CPM group's mean was 51.83 cm, a mean decrease of 0.50 cm. An interaction also occurred on postoperative Day 28. The mean score for the control group was 48.50 cm; it was 52.17 cm for the CPM group. The means and standard deviations of mid-thigh circumference are displayed in Table 16.

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Figure 3. Mean Mid-Thigh Circumference over Time for the Control and CPM Groups

T1: Preoperative
T2: Postoperative Day 1
T3: Postoperative Day 7
T4: Postoperative Day 28
Table 16
Means and Standard Deviations of Mid-Thigh Circumference in Centimeters

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Control</th>
<th>CPM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Pre-op</td>
<td>49.50</td>
<td>9.16</td>
</tr>
<tr>
<td>Post-op</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 1</td>
<td>52.33</td>
<td>8.33</td>
</tr>
<tr>
<td>Day 7</td>
<td>50.50</td>
<td>9.50</td>
</tr>
<tr>
<td>Day 28</td>
<td>48.50</td>
<td>9.50</td>
</tr>
<tr>
<td>Marginal Means (Treatments)</td>
<td>50.21</td>
<td>52.17</td>
</tr>
</tbody>
</table>

Crutch and Medication Use

Descriptive statistics were used to determine subjects' average crutch and medication use. No difference was apparent in postoperative crutch or medication use between the CPM and control groups. The CPM group used crutches an average of 3.78 days, SD = 2.56. The control group averaged 4.55 days on crutches, SD = 2.03. The CPM group took medication for an average of 2.11 days, SD = 2.08. The control group used
medication an average of 2.88 days, SD = 2.88.

Table 17 presents the means and standard deviations for postoperative crutch and medication use.

Table 17
Means and Standard Deviations of Crutch and Medication Use in Days

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Control</th>
<th>CPM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Crutches</td>
<td>4.55</td>
<td>2.03</td>
</tr>
<tr>
<td>Medication</td>
<td>2.88</td>
<td>2.49</td>
</tr>
</tbody>
</table>

Discussion

Based on the results of this study, there was no significant difference between CPM and control groups in ROM, strength, or circumference. However, there was a significant interaction effect between treatments and time when extension ROM, joint line circumference and mid-thigh circumference were analyzed one day postoperatively. There was also a significant effect 28 days postoperatively for mid-thigh circumference. In addition, there were significant differences within subjects over time for all dependent variables.
The significant interaction effect, revealed on the first day following arthroscopy for extension ROM, was expected from the use of CPM treatment. The machine was set at zero degrees, or full extension; thus the knees in the CPM group were moved into full extension for one hour after surgery. Conversely, the control knees were held in slight flexion while positioned on a pillow in the recovery room. The significant interaction effect demonstrated the day after surgery for joint line circumference was also related to extension ROM. Since there was less edema in the CPM knees, they were more easily moved into full extension. The decreased edema demonstrated in this study was consistent with the results of Danzig et al., (1987) and Skyhar et al., (1985) who found that CPM increased fluid and metabolite transport out of the joint.

There was not a significant interaction effect for flexion ROM. This could also be explained by the CPM parameters. The machine was set at 75 to 80 degrees of flexion. This was only 60 to 70% of full flexion for the subjects; the end range of motion was not stressed. However, raw scores for flexion one day after surgery revealed that only one subject in the CPM group did not achieve flexion of 90 degrees or more, whereas eight subjects in the control group had knee flexion of 85
degrees or less. Due to limitations of the machine and subject comfort, full flexion was not achieved from treatment. The author postulated that this prevented a significant difference in flexion between groups.

For each dependent variable the difference within subjects over time was significant. This too was expected. It was expected that initial measurements would be the greatest for strength and ROM, and the smallest for circumference. Then, one day after surgery, the opposite was expected, due to damage from tissue manipulation. It was further expected that healing would occur over time, and therefore measurements would gradually improve toward the levels recorded prior to surgery. Data supported the above expectations.

Although the CPM group averaged fewer days of crutch and medication use, the difference was small, 0.77 days for both parameters. An attempt was made to analyze days off work, however, due to the number of subjects not working (n = 8), or with employer policies specifying minimum time off after surgery (n = 5), sample size was too small to be meaningful.

The differences in degrees of freedom for the different circumferences were due to missing data. Some subjects wore clothing at follow-ups that could not be
raised above the knee for measurements of the lower and mid-thigh. The significant interaction effect for mid-thigh circumference 28 days postoperatively was an interesting phenomenon. Noyes et al., (1987) reported a decreased thigh girth of 2 to 3 cm, 21 days following arthroscopic ligament repair. The decreased girth mainly reflected a loss of muscle mass. The present study did not reveal the same girth decrease. The control group demonstrated a 1 cm girth decrease on day 28 postoperatively. The CPM group's decrease was a negligible 0.16 cm. The difference between findings may have been due to the type of arthroscopic procedure performed. Ligament repair is a more time consuming and invasive procedure with more tissues involved, than the meniscus or plica removals performed in this study.

Although indicated, the author was hesitant to conclude that CPM helped prevent quadriceps atrophy, due to small sample size and since analysis of strength measurements did not support said conclusion.

The pumping mechanism of CPM (O'Driscoll et al., 1983a) explained the interaction effect on postoperative Day 1 for circumference 15 cm proximal to the superior border of the patella. The CPM helped remove fluid from the area so that the entire thigh was not edematous. However, it did not entirely eliminate swelling, as
evidenced by the lack of interaction effect for both suprapatellar and lower thigh circumferences. The author postulated that with a larger sample size and greater statistical power, a difference would have been revealed for all circumferences.

The time on CPM may not have been sufficient to produce the effects hypothesized by the author. When used on humans, CPM was mostly utilized as an ongoing treatment. In addition, it was used following surgeries more extensive than the surgery performed in the present study. CPM was used after either open or arthroscopic procedures. The arthroscopic procedures involved manipulation or ligament repair. Some of the studies using rabbit subjects revealed CPM benefits after one hour (Danzig et al., 1987 and Skyhar et al., 1985). However, it is questionable how much extrapolation can be made to human subjects. The researcher was not able to achieve CPM placement for longer than one hour without disruption of normal postoperative routine. Perhaps in an out-patient, research-oriented facility, time could have been more easily manipulated.

A drawback of this study was its small sample size. A subject pool was not available and encouragement to participate in the study was offered solely by the examiner. In addition, it was difficult to get subjects
to return for measurement 28 days postoperatively. The author believed this study would have been more easily researched in concert with a physician who specialized in performing arthroscopies on a specific subject population. For example, a sports medicine program may have had a larger subject population available for study. With more subjects there would have occurred more degrees of freedom, and therefore greater statistical power. Some of the differences revealed in this study may have been significant with a larger sample size.

The lack of difference between groups in strength may have been due to experimental design. The first postoperative strength test occurred one week after surgery. Three subjects from the control group were unable to register torque at that time interval, whereas all subjects in the CPM group had sufficient strength to register torque. Testing earlier than one week may have revealed significant differences between groups. However, the physicians and investigator involved in this study believed earlier testing may have resulted in soft tissue damage due to insufficient healing time.
CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

The scope of this study was to determine the effect of continuous passive motion (CPM) after arthroscopy on knee range of motion (ROM), strength, and circumference. The research was discussed under the following headings; (a) Summary, (b) Findings, (c) Conclusions, and (d) Recommendations.

Summary

The purpose of this study was to determine the benefit of CPM after knee arthroscopy. The twenty subjects investigated were divided into two groups of ten, a control group and experimental (CPM) group. Male and female subjects were distributed evenly between groups. There was no significant difference in age or tourniquet time between the groups.

Measurements of knee ROM and circumference were taken at the following four intervals; (a) one to two hours prior to surgery, (b) one day after surgery, (c) one week after surgery, and (d) four weeks after surgery. Strength was measured at all intervals except one day following surgery. ROM was measured with a
metal 180 degree goniometer. Strength was measured on the Cybex II with computer data reduction, and expressed in percent body weight. Circumference was measured in centimeters using a retractable cloth tape measure. Surgery was performed by one of two physicians. Marcaine, a long lasting local anesthetic, was injected into the knee. In addition, postoperative medication and crutch use after surgery were recorded.

Eight split-plot factorial analyses of variance (ANOVAs) were calculated by computer using the following dependent variables: (a) extension ROM, (b) flexion ROM, (c) extension strength, (d) flexion strength, (e) joint line circumference, (f) suprapatellar circumference, (g) circumference 5 cm proximal to the superior patella, and (h) circumference 15 cm proximal to the superior patella. The independent variables were treatment (CPM) and time. In addition, descriptive statistics were used to analyze postoperative crutch and medication use.

Findings

The hypothesis that CPM after arthroscopy increased knee ROM was partially supported. There was no significant difference between the CPM and control groups for extension $F(1, 10) = 1.76, p < .05$, or flexion $F(1, 11) = 1.96, p < .05$. There was a
significant difference within subjects over time for both extension $F(3, 30) = 41.69, p < .05$, and flexion $F(3, 33) = 31.27, p < .05$. There was a significant interaction effect between treatments and time for extension $F(3, 30) = 3.96, p < .05$. This occurred on postoperative Day 1.

The hypothesis that CPM after arthroscopy would increase performance on a strength test was not supported. There was no significant difference between the CPM and control groups for extension $F(1, 11) = 0.01, p < .05$, or flexion $F(1, 11) = 0.71, p < .05$. There was a significant difference within subjects over time for both extension $F(2, 22) = 6.68, p < .05$, and flexion $F(2, 22) = 5.55, p < .05$.

The hypothesis that CPM after arthroscopy would decrease edema was partially supported. There was no significant difference between the CPM and control groups for circumference measured at (a) joint line, $F(1, 11) = 0.47, p < .05$; (b) superior patella, $F(1, 11) = 0.15, p < .05$; (c) lower thigh, $F(1, 6) = 0.00, p < .05$; or (d) mid-thigh, $F(1, 4) = 0.10, p < .05$. There was a significant difference within subjects over time for all circumferences (a) joint line, $F(3, 33) = 28.95, p < .05$; (b) superior patella, $F(3, 33) = 20.85, p < .05$; (c) lower thigh, $F(3, 18) = 6.88, p < .05$; and
(d) mid-thigh, $F(3,12) = 4.03, p < .05$.

There was a significant interaction effect on postoperative Day 1 between treatment and time for joint line circumference $F(3, 33) = 3.59, p < .05$. There was also a significant interaction effect between treatment and time for mid-thigh circumference $F(3, 12) = 5.92, p < .05$. This occurred on postoperative Days 1 and 28.

Conclusions

Based on the results of this study, CPM decreased joint line and mid-thigh edema with resultant increased extension ROM one day after knee arthroscopy. It had no effect on postoperative days 7 and 28. CPM use did not influence strength, but it may have prevented decreased mid-thigh girth 28 days postoperatively. Finally, CPM did not affect postoperative crutch or medication use.

Recommendations

Further study is needed to discern the optimal time for CPM placement after arthroscopy. The author postulated that a longer time on CPM may have revealed a significant benefit in the parameters measured in this study. In addition, a study with a larger sample size may have demonstrated significant differences in the variables discussed in this paper, due to more degrees
of freedom yielding greater statistical power. If the above research revealed significant benefit of CPM, application would be universal; most people would want to recover from surgery as quickly as possible. Use of CPM after arthroscopy would perhaps be most critical to the athlete, for whom early return to activity is crucial.
INFORMED CONSENT FORM

CONTINUOUS PASSIVE MOTION AFTER KNEE ARTHROSCOPY

A study is being done at Butterworth Hospital to investigate the effects of continuous passive motion (CPM) after arthroscopic knee surgery. The CPM machine is a device which passively bends and straightens the knee. It is currently routinely used at Butterworth Hospital after total knee replacement surgery, and after arthroscopy at other facilities. The physical therapy procedures used in this study are also routine, so that subjects participating in this study will not incur any risks from said participation.

Subjects included in this study will be systematically assigned to one of two groups. Some subjects will receive CPM and some will not receive any treatment. All subjects will, however, have measurements of their strength, range of motion, and circumference taken prior to surgery, and also one day, one week, and one month after surgery. One benefit of this study to the subjects will be the close monitoring of their progress, allowing any problems with their recovery to be addressed immediately. The study may reveal an improved method of patient treatment after arthroscopy; its benefits would thus apply to future patients.

All patients involved in research projects will be treated in the same manner and receive the same level of care as patients at Butterworth Hospital who are not involved in research projects. They will be advised if compensation or reimbursement for medical treatment is available if injuries should develop as a direct result from their participation in a project. Butterworth Hospital does not assume any liability for cost, medical care or compensation for injuries directly caused by the research protocol.

The orthopedist of each subject is fully aware of, and has approved the parameters of the study, and will disqualify any subject he believes should not participate in the study. Any questions concerning the study or subject's rights should be directed to Lisa Bauman, 774-1690.

I have read and understand the above information. I voluntarily consent to participate in this study, recognizing that I am free to discontinue my participation at any time. All results will be strictly confidential, and participants in the study will remain anonymous.

Signature ______________________  Date ________________
TO: Lisa Bauman
    Mary Dawson

FROM: Ellen Page-Robin, Chair

RE: Research Protocol

DATE: December 2, 1986

This letter will serve as confirmation that the Board's concerns regarding
your research protocol, "Use of Continuous Passive Motion after Arthroscopic
Knee Surgery," have been clarified and the research has been approved. The
Board anticipates receiving a copy of the Butterworth approval.
If you have any questions, please contact me at 383-4917.
November 21, 1986

Ms. Lisa Bauman, RPT
Physical Therapy Department
Butterworth Hospital
100 Michigan, N.E.
Grand Rapids, MI 49503

Dear Lisa:

This is written to inform you that on Tuesday, November 18, 1986, the Human Rights Committee of Butterworth Hospital approved your study to determine the effects of continuous passive motion (CPM) after knee arthroscopy pending the inclusion of the following statement to the informed consent document:

All patients involved in research projects will be treated in the same manner and receive the same level of care as patients at Butterworth Hospital who are not involved in research projects. They will be advised if compensation or reimbursement for medical treatment is available if injuries should develop as a direct result from their participation in a project. Butterworth Hospital does not assume any liability for cost, medical care or compensation for injuries directly caused by the research protocol.

Please be advised that any unexpected, serious, adverse reactions must be reported to the Human Rights Committee; any emergency changes in the study that are made to protect the life of the subject must be reported to the Human Rights Committee within five (5) days; and all changes made to the study after initiation require prior approval of the Human Rights Committee before the changes are implemented.

The Human Rights Committee of Butterworth Hospital requests that before you begin your study, you provide the Committee with an informed consent document that includes the statement about availability of compensation for research subjects as well as submit a report regarding the status of your project by May 18, 1987.

Sincerely,

[Signature]

Philip H. McCorkle, Jr.
Secretary, Human Rights Committee

PHM/sb
BIBLIOGRAPHY


