Research Report

Aquatic and Land Based Therapy vs. Land Therapy on the Outcome of Total Knee Arthroplasty: A Pilot Randomized Clinical Trial

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Abstract

Background and Purpose: Currently, there is a lack of objective data that supports the effectiveness of combining aquatic physical therapy with land based therapy. The purpose of this study was to determine the effectiveness of combining aquatic physical therapy with land based therapy verses solely land based therapy on pain, range of motion (ROM), swelling, as well as symptoms and function via the KOOS questionnaire in 30 patients that have undergone unilateral TKA. **Subjects:** 30 subjects who have undergone unilateral TKA were randomly assigned to either the integrated (aquatic and land) group, or the control (land) group (15 subjects in each group). **Methods:** Outcomes measured for comparison included pain, swelling, ROM and in addition symptoms and function via the Knee Injury and Osteoarthritis Outcome Scores questionnaire (KOOS). **Results:** Immediately after exercise cessation (6 weeks), a significant improvement of knee flexion ROM was observed in the integrated group. No effect was observed in pain, swelling, and KOOS. At 6-months after cessation of treatment, the follow-up KOOS questionnaire demonstrated a significant improvement in the symptomatic category favoring the integrated group **Conclusion:** These findings suggest that after undergoing a unilateral TKA an individual would benefit from a treatment program consisting of both aquatic and land exercises that would greatly encourage improvements in ROM after a 6-weeks as well as improved symptomatic KOOS reports after 6-months.

Key Words: pain, swelling, KOOS, range of motion, aquatic

Introduction

Total Knee Arthroplasty (TKA) continues to demonstrate success in relieving knee pain and improving function for patients suffering from knee pain secondary to injury and degenerative joint disease.[1] The number of TKAs performed each year in the United States continues to increase incrementally. A total of 160,000 TKAs were performed in the United States in 1991. In 1994, the number of procedures rose to 210,000 resulting in healthcare costs exceeding $5 billion.2 Data collected in 2004 continued to demonstrate a significant increase in the number of TKAs performed, which rose annually to 478,000. A study presented at the 2006 Annual Meeting of American Academy of Orthopaedic Surgeons projected a 673% increase to 34.8 million surgeries performed annually by the year 2030. There are a number of factors contributing to this increase which include the increasingly aging population, the obesity epidemic, and the indication for TKA extending to younger individuals as well as a population that desires to stay more physically active.

The most common symptoms a patient experiences after undergoing a TKA are pain, swelling, stiffness, muscle weakness and limited ADL'S. Traditional land based physical therapy rehabilitation for patients following a TKA typically involves some combination of active assistive range of motion, strengthening, ADL, gait training, functional training and patient education.[3] Numerous studies have been performed on the effectiveness of land based physical therapy following TKA.[4-11]

Aquatic Physical Therapy may offer an alternative intervention to traditional Physical Therapy Rehabilitation following TKA.[12] There are many reported benefits of Aquatic Physical Therapy. Aquatic studies have shown improvements in ROM, swelling, pain reduction, stiffness and quality of life after TKA. However, these studies were primarily case study in nature or were not compared to another form of treatment.[2,13]

Currently, there's a paucity of literature investigating the therapeutic benefits of utilizing an integrated (aquatic and land) rehabilitation protocol for individuals who have undergone a TKA.[14] Therefore, the purpose of this study was to investigate the effectiveness of an integrated treatment approach including aquatic with land based therapy verses land therapy alone in improving range of motion, pain, swelling, and functional status in patients with unilateral TKA due to OA.

Methods

Subjects

This randomized clinical trial was conducted between May 2005 and July 2006 at Rehab 3 at Marshbrook in Somer-

sworth New Hampshire. Consecutive subjects were referred to physical therapy by one of two orthopedic surgeons after undergoing a unilateral TKA within the previous six weeks.

Inclusion Criteria

1. Subjects between the 50 and 80 years of age.
2. Surgery was performed by one of two participating orthopedic surgeons.
3. Subjects had undergone unilateral TKA secondary to osteoarthritis.

Exclusion Criteria

1. Red flags noted in the patient's admission medical questionnaire. I.e. cardiac

   Precautions, previous joint replacements, etc.
2. Extremely fearful of water.
3. Bilateral TKA.
4. Insurance limitations not allowing them to participate in aquatic and land based the same treatment session.
5. Inability to comply with the treatment or follow-up schedule.

All patients that met eligibility criteria and agreed to participate in the study signed a consent form approved by the IRB. This study was approved by the Patient Advocacy Council's Institutional Review Board, Mobile, AL.

All participating subjects underwent a standardized history, physical examination and completed a number of self-report measures. The history and differential diagnosis was completed by the lead author (RM) for all subjects. The history included a standard patient history form that each subject completed to flag any contraindication to subject participation. The lead author also obtained a self-report measure of pain as well as the administration of the Knee Osteoarthritis Outcome Score (KOOS) used to measure subject's baseline functional status. Baseline measurements of active and passive knee range of motion, and girth measurements were obtained by one of two blinded Data Collection Technicians (DCT) who were both physical therapists employed 40 hours per week at Rehab 3 at Marshbrook.

Outcomes

Numeric Pain Rating Scale (NPRS): An 11-point NPRS ranging from 0-10, 0 being described as "no pain at all" and 10 being "the worst pain imaginable." Patients rated their current level of pain, and the NPRS exhibits a high test/retest reliability of numeric pain rating scales ($r=0.75 - r=0.83$; $p<0.001$).[15] A 2 point change on the NPRS is necessary to exceed bounds of measurement error and to be considered clinically meaningful.[16]

Circumferential Measurements: Circumferential measurements of the knee were taken with the patient in a supine position. Measurements were taken by one of two DCT's that were blinded to the subject group assignment. The landmarks that were evaluated are mid-patella, 3" proximal to the center of the patella, and 6" distal to the center of the patella. All measurements were taken with the same non-elastic tape measure. Reliability of lower extremity girth measurement with a non-elastic tape measure following knee surgery has been documented by Ross and Worrell which demonstrated excellent reliability for intra-session and inter-session testing (ICC>.90).[17] Additionally, a pilot study investigating the reliability of circumferential measurements of the DCT's for this study was performed. Data was analyzed utilizing Statistical Package for the Social Sciences Version 13 using an intra-class correlation coefficient (2, 1). This pilot study demonstrated excellent inter-rater reliability for girth measurements of the mid-patella, 3 inches proximal to the mid-patella, and 6 inches distal to the mid-patella (0.994, 95% CI 0.989-0.997).

Range of Motion (ROM): Both knee active ROM and passive ROM was taken by one of two blinded DCT's. Measurements were taken with a standard plastic goniometer with the subjects in supine. The testing procedure used in this study has been described by Norkin & White.[18] Landmarks used for measurement were the greater trochanter of the femur, head of fibula, and lateral malleolus. Patients were instructed to slide his/her heel towards the buttocks, bending the knee to their subjective reported tolerance to discomfort of the procedure; a measurement was then taken and recorded. The DCT's then instructed patient to relax while applying a gentle passive over pressure into flexion again to the patient's subjective reported tolerance to the discomfort of the procedure; another measurement of knee flexion was then taken and recorded. With the patient remaining in the supine position, the same procedure was used to obtain a knee extension measurement. The reliability and validity of the goniometric measurements has been documented in a study by Gogia, and Braatz, inter-test reliability ($r=.98$; ICC=.99) and validity ($r=.97-.98$; ICC= .98-.99) were high.[19] Additionally, a pilot study investigating the inter-rater reliability of range of motion measurements of the DCT's for this study was performed to assure that reliability of measurements would be adequate. Data was analyzed utilizing Statistical Package for the Social Sciences Version 13 using an intra-class correlation coefficient (2, 1). The results of this pilot study demonstrated excellent inter-rater reliability for active flexion (0.99, 95% CI 0.987-0.998), passive flexion (0.993, 95% CI 0.981-0.997), active extension (0.935, 95% CI 0.870-0.968), and passive extension (0.934, 95% CI 0.868-0.968).

Knee Osteoarthritis Outcome Score (KOOS): Subjects short and long term symptoms as well as function were measured using the KOOS. All participants of the study completed the KOOS at baseline, six weeks, and returned via mail at six months. The KOOS index is an extension of the Western Ontario and McMaster University Osteoarthritis Index (WOMAC), the most commonly used outcome instrument for assessment of patient's with relevant injury and knee osteoarthritis. Previous studies have demonstrated the

KOOS index to be a more responsive instrument for knee conditions compared to the WOMAC.[20] The KOOS holds five separately scored subscales including pain, symptoms, function/daily living (ADL), function/sport recreation (SPORT/REC), and quality of life (QOL). For the purpose of this study, the SPORT/REC component of the KOOS was eliminated from the survey due to the intensity of the activities in which the nature of the surgery would not allow patients to perform, such as twisting/pivoting, kneeling, and running on the surgical knee. The KOOS presents to be valid, reliable, and responsive self administered instrument used for short and long term follow-up of several orthopedic interventions such as anterior cruciate ligament reconstruction, meniscectomy, and TKA.[20] The test/retest reliability is acceptable for all subscales and ranges between r=0.65-0.78 and the questionnaire exhibits high internal consistency.[21]

Randomization

Randomization was performed using a random sequence table generated by computer prior to the initiation of the study. Group assignment was put on 3.5"x 5.5" card labeled "Land" or "Water and Land" to denote group assignment. Each card was then placed in a concealed envelope. Eligible patients that participated in this study were randomly assigned to either the land group or the integrated group by the evaluating physical therapist that chose one of the randomization envelopes.

Interventions

When designing the exercise programs for each treatment group attempts were made by the authors to select exercises that were similar in nature but not necessarily performed in the same medium. This was done in an attempt to equalize treatment times as wells as the amount of exercises between groups.

Land Physical Therapy

Subjects randomly assigned to participate in the land group received physical therapy on land two times a week for six weeks. The measurements of active and passive ROM, pain, and girth measurements were taken before and after each treatment session by one of two blinded DCTs. The KOOS survey was completed by each subject at baseline, six weeks, and six months. Each land patient received sixty minutes of physical therapy twice a week for six weeks. Land exercises consisted of various open and closed chain lower extremity exercises emphasizing lower extremity strength, balance, proprioception, and active and passive range of motion that were all timed with a stop watch. Refer to Appendix A for land exercise protocol. A one minute rest period between each exercise was given as patient needed.

Integrated Physical Therapy

Subjects randomly assigned to participate in the integrated group received physical therapy in the water and on land two times a week for six weeks. Measurements of active and passive ROM, pain, and girth were taken before and after each treatment session by a blinded DCT's. The KOOS survey was completed by each subject at baseline, six weeks, and six months. Patients received 30 minutes of aquatic therapy in a 92° therapeutic pool followed by 30 minutes of land physical therapy. Patients in the integrated group were given 15 minutes to change between aquatic and land therapy sessions. Land and aquatic exercises consisted of various open and closed chain lower extremity exercises emphasizing lower extremity strength, balance, proprioception, and active and passive range of motion, and all exercises performed were all timed with a stop watch. Refer to Appendix B for integrated exercise protocol. A one minute rest period between each exercise was given as patient needed.

Data Analysis

Data collected in this study was analyzed using the R Project for Statistical Computing. Baseline demographics and outcome measures were analyzed using a two-sample t-test to detect between-group differences, and the Wilcoxon Rank-Sum Test was used as an alternative measurement for cases where the data did not have a normal distribution. The Wilcoxon Rank-Sum test is a nonparametric test to examine both the direction of difference and the relative amount of difference between two dependent variables.[22] Baseline measurements of the dependent variable compared in this study included: pain level, active ROM knee flexion, active ROM knee extension, passive ROM knee flexion, passive ROM knee extension, girth measurement mid-patella, 6 inches distal to the mid-patella, and 3 inches proximal to the mid-patella, as well as Function via the KOOS. Components of the KOOS used for comparison include: Pain, Symptoms, Activities of Daily Living, and Quality of Life. A P value of $P<.05$ was considered statistically significant for all data analyzed.

Comparison of change from baseline to discharge (visit 1 to visit 12) of the dependent variables in this study was analyzed using the two-sample t-test and Analysis of covariance (ANCOVA). The two-sample t-test was used to detect between-group differences while the ANCOVA was used to equate groups on extraneous variables and to correct for heterogeneity among patients.

The four components of the KOOS investigated in this study were analyzed using the two-sample t-test and Wilcoxon Rank-Sum Test to compare outcome scores from baseline to discharge. Pair-wise differences for all subjects were obtained (measurement at discharge minus measurement at baseline), and the means of these "change in measurement" values were used for comparison between the two treatment groups. A P-value of .05 or less is considered a statistically significant change in outcome scores.

Results

From May 2005 to July 2006, 30 subjects satisfied the eligibility criteria, agreed to participate and provided informed consent. Fifteen subjects were randomly assigned to the integrated treatment group, and 15 to the control group. A

flow diagram of subject recruitment and retention can be found in figure 1. All patients with unilateral TKA referred to physical therapy agreed to participate and completed all components of the study including the 6 month KOOS follow-up. Baseline variables including pain, ROM, swelling, and KOOS for each group in this study are summarized in table 1. Significant differences were found among the two groups for a few of the baseline variables measure. The integrated group began therapy at a lower level than that of the land group. Differences in baseline measurements to include pain, ROM, and swelling were equated by analyzing the data using the ANCOVA. Baseline measurements of the KOOS demonstrate significant differences between the groups for all components with the exception of the symptoms score (p=.021). Data analysis demonstrated higher KOOS function rating in the control group at baseline as compared to the integrated treatment group. Uneven distribution of baseline KOOS measurements was corrected for using the Wilcoxon Rank-Sum Test.

P values for change in dependent measures between groups from visit 1 to visit 12 including pain, swelling and ROM is summarized in Table 2. Analysis of these dependent variables including pain, swelling, and knee extension ROM from visit 1 to visit 12 resulted in no significant difference between groups, however significant difference was found for knee flexion ROM (P=.045) favoring the integrated group.

Table 3 shows the P values for all measured components of the KOOS (baseline, 6 weeks, and 6 months). Comparison of KOOS from baseline to 6 weeks resulted in no significant difference in all categories, however a statistically significant difference was found in the Symptoms score favoring the integrated treatment group (p= .03) from 6 weeks to 6 months.

Discussion

This randomized clinical trial investigated the effectiveness of combining an aquatic and land based program verses solely a land based program for the treatment of unilateral TKA. This study demonstrated that a 6-week integrated physical therapy program improved knee flexion ROM as well KOOS Symptomatic reports which included swelling, grinding, clicking, bending and straightening the knee fully after 6 months. It is our belief that the integrated treatment group was able to increase knee flexion ROM greater than the land based group due to the order of the aquatic component of the research. The water temperature of the therapeutic pool was 92 degrees which may have encouraged relaxation, a decrease muscle guarding around the surgical joint and increased joint movement.[23] The buoyancy of water allowed a decrease in body weight limiting joint compressive forces promoting greater joint movements and a symmetrical gait pattern with less discomfort. The aquatic environment may have acted as a gaiting mechanism resulting in a decrease of pain and allowing for improved pain-free ROM during exercise. In addition, the hydrostatic pressure of the water could have encouraged edema reduction which may have influenced the reduction of pain and improved ROM.[24-26] Following the aquatic treatment with the land based treatment allowed for reinforcement of knee flexion ROM secondary the manual therapy, joint mobilizations and strengthening exercises performed after the aquatic exercise.

It is in the opinion of the authors that the symptoms category of the KOOS Index for the 6 month follow up was significantly improved in the integrated group secondary to the improved knee flexion ROM that was gained by utilizing the aquatic environment first. A recent study has shown continued improvements in Total Knee Arthroplasty for up to 26 weeks after surgery. The increased ROM gained after the 6 week treatment in the integrated group may have facilitated this continued long term progress.[27]

There have been numerous studies performed on the treatment of TKA and this study is not the first study to investigate the outcomes of aquatic therapy compared to land based therapy. However, most studies investigating the outcomes of aquatic therapy compared with land have been performed on patients with hip and/or knee injury or arthritis and not necessarily on TKA.[13,14,23,28-32] A case study investigating outcomes of a patient with bilateral TKA including an independent home exercise program for strengthening in combination with skilled physical therapy in an aquatic environment resulted in increased ROM and strength and a decrease in pain and girth measurements bilaterally.[2] A more recent study demonstrated aquatic therapy to be beneficial for patients with Osteoarthritis (OA) of the knee and/or hip resulted in reduced pain and joint stiffness as well as improved physical function, hip muscle strength, and quality of life.[13] Unfortunately, those participating in the aquatic therapy portion of the study were compared to a control group that received no skilled physical therapy intervention.

To our knowledge this is the first study to investigate an integrated treatment approach for TKA due to OA which has demonstrated encouraging results. Hopefully this studies result will encourage more therapists working in aquatic physical therapy to perform future research studies utilizing an integrated treatment protocol for various diagnoses.

Limitations

There are a few limitations of this present study that may affect the reproducibility and generalizability of this integrated treatment approach. This study used various exercise equipment both on land and in the water that may unavailable to all clinics. Furthermore, due to the high cost of building a therapeutic pool, not all clinics have pool available to them. It is possible to utilize community pools such as those in hotels and fitness centers; however the pools in hotels and fitness centers may not be at therapeutic temperature and may only be available at certain times of the day for therapy purposes. The land group subjects in this study used leg extension and flexion machines which again may not be available in all clinics.

Another component of this study effecting generalizability is the number of doctors involved as well as the number of treating therapists and clinics involved. Only two doctors from a small orthopedic practice that performed the TKA's for that practice were recruited for a referral base for this study. Also, this study was a single center study in which treatment was provided by one physical therapist and one physical therapist assistant as needed. Because of the above limitations this study was unable to generate a substantial sample size to reach true statistical significance. Only thirty subjects were able to be recruited for this study which influenced this study to be a pilot study rather than a true randomized clinical trial. Having more clinics involved as well as more doctors and treating therapists in this research study may have increased our sample size to over 100 to 200 subjects and would have contributed to the reproducibility and generalizability of the study. Also, having the subjects return to the clinic after the 6 month period for measurements of pain, ROM and swelling may given us more information of the subject's status.

The information from this pilot study may provide a basis for initiating future randomized clinical trials to investigate integrated protocols for the treatment of TKA's. These clinical trials should include multiple treatment groups in various orders and should include: Land treatment only, Pool treatment only, Pool then Land treatment and Land then Pool treatment. Additionally investigating lower extremity strength, balance and function using measurements such as the Leffs and 6 minute walk test may give the future researchers more insight to the effectiveness of performing integrated treatment protocols for TKA.

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Table 1.

Baseline Demographics of Participant Groups

Characteristic	Mean of Control Group (SD[a])	Mean of Integrated Group (SD[a])	P-Value
AROM Flexion	93.5(14.7)	84.8(11.6)	.08
AROM Extension	2.1(3.0)	2.4(5.8)	.87
PROM Flexion	99.4(16.0)	90.7(11.8)	.10
PROM Extension	0.80(1.5)	1.27(3.7)	.65
Girth 3" Proximal	46.6(6.0)	47.0(6.1)	.87
Girth Mid-Patella	43.9(3.3)	44.5(2.9)	.56
Girth 6" Distal	37.0(3.3)	38.0(3.7)	.41
KOOS:			
Pain	63.5(12.0)	43.9(15.8)	.01
Symptoms	47.6(10.3)	42.1(131)	.21
ADL	68.3(13.6)	55.7(14.7)	.02
QOL	38.3(16.5)	20.4(16.1)	.01

[a] SD=standard deviation

Table 2.

Baseline to Discharge/6 Week Comparison of Participant Groups

Characteristic	Mean difference between groups	P-value[a]	P-value[b]
AROM Flexion	1.880	.072	0.045
PROM Flexion	1.657	.109	0.116
AROM Extension	-0.614	.546	0.127
PROM Extension	-0.703	.490	0.218
Girth 3" Proximal	-3.662	.002	0.847
Girth Mid Patella	-2.084	.051	0.877
Girth 6" Distal	-2.521	.020	0.586
Pain	-2.707	.011	0.678

[a] Analyzed with two-sample t-test not corrected for baseline differences

[b] Analyzed with ANCOVA to account for differences in baseline measures

Table 3.

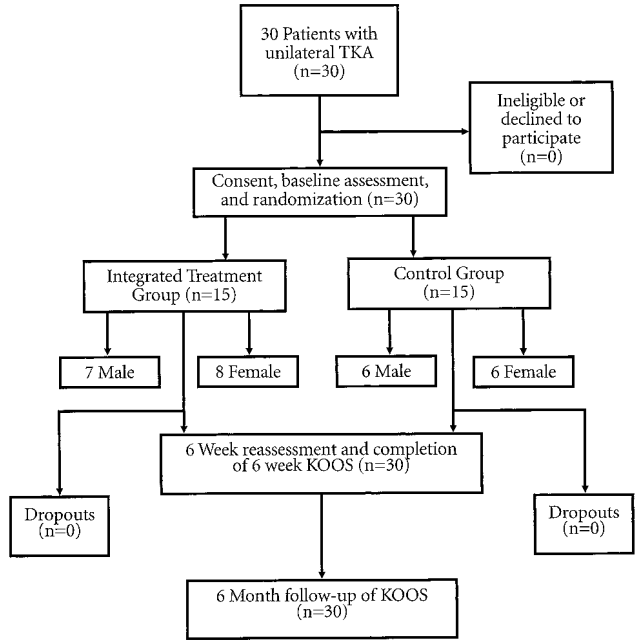
KOOS comparison of participant groups at 6 weeks and 6 months.

	Baseline to 6 Weeks		6 Weeks to 6 Months	
	Mean difference	P-Value[a]	Mean difference	P-Value[a]
Pain	7.6	.35	12.0	.30
Symptoms	10.1	.49	16.1	.03
ADL	7.0	.12	11.3	.42
QOL	8.8	.13	12.3	.40

[a] Analyzed with the Wilcoxon Rank-Sum Test to account for differences in baseline measures.

Figure 1.

Flow of participants through the trial.



Appendix A.

Manual Therapy

Exercise	Description of Exercise	Exercise Prescription
Recumbent Bicycle	Seated on Recumbent bike, peddling so that a gentle stretch is felt.	7 minutes
Total Gym Squats	With patient in a semi-supine position on the total gym sled, have patient walk feet forward on the platform so that knees don't go over the toes when squatting. Instruct patient to squat until a gentle stretch is felt.	Hold 30 Repeat 6 times
Stair Squats	Standing on 2nd step with feet shoulder width apart holding onto the railings with hands. Have patient squat down keeping heels down on the step, then return to standing position	Repeat exercise repetitiously for 30 seconds Repeat 6 times
Knee Extension Machine	Patient properly set-up on seated nautilus knee extension machine, instruct patient to extend both knees, and then slowly lower them. Adjust weight to appropriate level for each individual patient.	Repeat exercise repetitiously for 30 seconds Repeat 6 times
Hamstring Curl Machine	Patient properly set-up on seated nautilus hamstring curl machine, instruct patient to bend knees as far as they can then slowly extend back to starting position. Adjust weight to appropriate level for each individual patient.	Repeat exercise repetitiously for 30 seconds Repeat 6 times
Forward Step-ups	Have patient put one foot flat on top of a 6-8" step with the other foot flat on the floor. Instruct patient to step up bringing the other foot up onto step then step back down with the same foot.	Repeat step-ups for 45 seconds. Repeat 2 times
Lateral Step-ups	Have patient stand with a 6-8" step to the side of them, put one foot flat on top of the step. Instruct patient to step up bringing the other foot up onto step. Step back down with the same foot.	Repeat step-ups for 45 seconds Repeat 2 times
Single Leg Balance	Instruct patient to stand on one foot (surgical limb) without putting the other foot down.	Hold 30 seconds Repeat 6 times
Stair Lunge Stretch	Instruct patient to put one foot flat on top of a 12-24" step, lunge forward bending knee until a tolerable stretch is felt.	Hold 30 seconds Repeat 6 times
Hamstring Stretch on Stairs	Have patient standing with one foot on the floor of the pool, and the heel of the opposite foot on a 12-24" step keeping the knee straight. Instruct patient to lean forward keeping the back straight until a comfortable stretch is felt.	Hold 30 seconds Repeat 6 times
Manual Therapy:		
Scar Massage	Massage scar in perpendicular direction and with moderate pressure so that the scar and skin is moving side to side.	3 minutes
Medial Patellar Mobilizations	Passively move the patella in the medial direction.	1 ½ minutes
Superior Patellar Mobilizations	Passively move the patella in the superior direction.	1 ½ minutes
Manual Hamstring Stretch	With patient in supine position and heel of foot on a ½ foam roll, put one hand just above the knee and the other hand just below the knee. Gently push knee toward table until patient reports a gentle stretch is felt in the Hamstrings.	Hold for 30 seconds Repeat 6 times
Manual Quadriceps Stretch with Posterior/ Anterior Joint Mobilizations	With patient in a seated position with both legs bent hanging over the side of the table, place hands around knee perform repeated PA mobilizations of the knee followed by a passive flexion stretch stabilizing femur.	Complete Joint mobilizations for 10 seconds Passive Knee Flexion Stretch Hold for 30 seconds Repeat 6 times

Appendix B.

Integrated Aquatic Exercise Program

Exercise	Description of Exercise	Exercise Prescription
Shallow Water Exercises: (Water depth = 3' 8")		
Walking Forward	Instructing patient to standing up tall, have patient walk forward with reciprocal arm swing.	2 Lengths of the pool*
Walking Backward	Instructing patient to standing up tall, have patient walk backward extending hip with reciprocal arm swing.	2 Lengths of the pool*
Walking Sideways with semi-squat	Have patient stepping out to the side with one foot so that legs are separated, instruct patient to semi-squat keeping heels down on the floor, then stand back up stepping together with opposite foot.	2 Lengths of the pool*
Clap Under	Instruct patient to walk forward bringing one knee up as if to march, clapping hands under thigh.	2 Lengths of the pool*
Clap Behind	Instruct patient to walk forward bringing one heel up towards buttocks keeping thigh vertical while simultaneously reaching both hands behind to touch foot.	2 Lengths of the pool*
Straight Leg Raise Walk	Instruct patient to walk forward kicking one leg out straight in front of them.	2 Lengths of the pool*
Stair Lunge Stretch	Instruct patient to put one foot flat on top of a 12-24" step, lunge forward bending knee until a tolerable stretch is felt.	Hold 30 seconds Repeat 5 times
Stair Squat	Instruct patient to put both feet shoulder width apart and flat on a 12-24" step, squat down holding the side of the pool until a comfortable stretch is felt.	Hold 10 seconds Repeat 10 times
Hamstring Stretch	Have patient standing with one foot on the floor of the pool, and the heel of the opposite foot on a 12-24" step keeping the knee straight. Instruct patient to lean forward keeping the back straight until a comfortable stretch is felt.	Hold 30 seconds Repeat 5 times
Forward Step-up	Have patient put one foot flat on top of an 8-12" step with the other foot flat on the floor. Instruct patient to step up bringing the other foot up onto step then step back down with the same foot.	Repeat 15 times Do 2 sets
Lateral Step-up	Have patient stand with a 8-12" step to the side of them, put one foot flat on top of the step. Instruct patient to step up bringing the other foot up onto step. Step back down with the same foot.	Repeat 15 times Do 2 sets
Kickboard Marching	Have patient to put a kickboard under the surgical leg's foot. Instruct patient to slowly raise the kickboard bending the knee towards their chest as if to march.	Repeat 30 times
Single Leg Balance with Kickboard Push and Pull	Have patient stand on one foot (surgical leg). Instruct patient to holding the sides of the kickboard pushing the kickboard perpendicular in to the water then push forward and pull back with the kickboard while keeping their balance.	Hold balance on single leg for 30 seconds Repeat 2 times
Deep Water Exercises: (Water depth = 7' 6")		
Heel to Buttocks	Hanging vertical in the water with appropriate flotation device, have patient bring one heel up towards buttocks keeping the thigh vertical.	Repeat for 30 seconds
Single Knee to Chest	Hanging vertical in the water with appropriate flotation device, have patient bend one knee up as if to march keeping the opposite leg vertical.	Repeat for 90 seconds
Double Knee to Chest	Hanging vertical in the water with appropriate flotation device, have patient bend both knees up toward chest then return to vertical position.	Repeat for 90 seconds
Prone Single Knee to Chest	With a long barbell under each arm have patient go into prone position on the water. Keeping back and buttocks on the surface of the water have patient bring one knee up toward their chest while keeping the other leg straight out in back.	Repeat for 90 seconds
Prone Double Knee to Chest	With a long barbell under each arm have patient go into prone position on the water. Keeping back and buttocks on the surface of the water have patient bring both knees up toward their chest.	Repeat for 90 seconds
Bicycling	With patient in a vertical position have patient peddle legs as if to ride a bicycle.	Repeat for 90 seconds
Land Exercises		
Recumbent Bicycle	Seated on Recumbent bike, peddling so that a gentle stretch is felt.	3 minutes
Total Gym Squats	With patient in a semi-supine position on the total gym sled, have patient walk feet forward on the platform so that knees don't go over the toes when squatting. Instruct patient to squat until a gentle stretch is felt.	Hold 30 Repeat 3 times
Forward Step-ups	Have patient put one foot flat on top of a 6-8" step with the other foot flat on the floor. Instruct patient to step up bringing the other foot up onto step then step back down with the same foot.	Repeat step-ups for 45 seconds.
Lateral Step-ups	Have patient stand with a 6-8" step to the side of them, put one foot flat on top of the step. Instruct patient to step up bringing the other foot up onto step. Step back down with the same foot.	Repeat step-ups for 45 seconds
Single Leg Balance	Instruct patient to stand on one foot (surgical limb) without putting the other foot down.	Hold 15 seconds Repeat 6 times
Manual Therapy:		
Scar Massage	Massage scar in perpendicular direction and with moderate pressure so that the scar and skin is moving side to side.	2 minutes
Medial Patellar Mobilizations	Passively move the patella in the medial direction.	1 minute
Superior Patellar Mobilizations	Passively move the patella in the superior direction.	1 minute
Manual Hamstring Stretch	With patient in supine position and heel of foot on a ½ foam roll, put one hand just above the knee and the other hand just below the knee. Gently push knee toward table until patient reports a gentle stretch is felt in the Hamstrings.	Hold for 30 seconds Repeat 3 times
Manual Quadriceps Stretch with Posterior/ Anterior Joint Mobilizations	With patient in a seated position with both legs bent hanging over the side of the table, place hands around knee perform repeated PA mobilizations of the knee followed by a passive flexion stretch stabilizing femur.	Complete Joint mobilizations for 10 seconds Passive Knee Flexion Stretch Hold for 30 seconds Repeat 3 times

* 1 Length=40 feet