Use of the Functional Movement Screen ™ Corrective Exercises to Address Strength Deficits in a 55 Year Old Female Status Post L5-S1 Discectomy

A Capstone Project for PTY 768
Presented to the Faculty of the Department of Physical Therapy
Sage Graduate School

In Partial Fulfillment
of the Requirements of the Degree of
Doctor of Physical Therapy

Hannah Solomon
May, 2010

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Use of the Functional Movement Screen ™ Corrective Exercises to Address Strength Deficits in a 55 Year Old Female Status Post L5-S1 Discectomy

Hannah Solomon, SPT

Abstract

Background and Purpose: This case report describes the use of the Functional Movement Screen™ (FMS) corrective exercises in addition to a traditional strengthening and rehabilitation program in the treatment of a 55 year old female status post L5-S1 discectomy. The aim of this case report was to determine if the FMS corrective exercises in addition to a traditional rehabilitative program are useful in increasing trunk strength and stability, flexibility, ROM, and ADL's in a person post L5-S1 lumbar discectomy. Case Description: The individual in this case report is a 55 year old female department of transportation laborer. She received outpatient physical therapy 3 times per week for a duration of 11 weeks. A dynamic strengthening program was provided using several of the FMS corrective exercises in conjunction with other exercises to provide a comprehensive rehabilitative program that focused on improving strength and return to work. Outcomes: At the completion of treatment improvements were noted in strength, flexibility, activities of daily living, and special and functional testing. Her lower body strength improved from 0.5 to 1.5 manual muscle testing grades and trunk range of motion improved from 20% to 55%. She also had significant improvements in ADL's such as tolerance to sitting, walking, and bending at the trunk yet was not able to return to work. She was discharged to a local fitness club. Discussion: The findings suggest that FMS corrective exercises when used in adjunct to a traditional treatment program may be useful in the rehabilitation of individuals status post L5-S1 discectomy. However further experimental research is needed utilizing the corrective exercises to determine the efficacy and usefulness of the FMS corrective exercises in the physical therapy setting.

Introduction

Lumbar disc herniations are the most common cause of lumbar radiculopathy. In North America, lumbar disc herniations affect 1% to 2% of the population,[1] with ninety-five percent occurring in one of the lower intervertebral discs.[2] A disc herniation at the level of L5 and S1 affects the corresponding nerve roots resulting in sciatica, bowel and bladder dysfunction, postural control, and lower extremity impairments.[3,4]

Discectomies are currently the most frequently utilized surgical intervention to address spinal nerve and nerve root compression resulting from intervertebral disc herniation. Surgical intervention has been reported in 2% to 10% of people with lumbar disc herniation, with approximately 200,000 discectomies performed annually in North America.[1] A study by Lurie et al[3] explored the differences in outcomes over a 2 year period between upper and lower lumbar spine discectomies finding that individuals with upper spine discectomies (L2-L3 and L3-L4) had better outcomes after surgical procedure as compared to lower spine discectomies (L4- L5 and L5-S1). Outcomes in individuals with lower spine discectomies were worse in all aspects of treatment after surgery with regards to pain, quality of life, and disability after operative treatment.

Following surgery, residual sciatic pain is reported by 10% to 30% of individuals,[5] whereas residual back pain is reported by 30% to 40%.[6,7] Only 80% of those having undergone discectomy return to work within 12 months after surgery.[8,9] Approximately half of those who undergo disc herniation experience a preoperative as well as postoperative reduction of muscle strength and endurance corresponding to the affected nerve root distribution which is one of the reasons that the return to work rate is so low after undergoing discectomy surgery.[2,10,11] The aforementioned low return to work rate after surgical

discectomy implicates the necessity for an intense and comprehensive rehabilitative program for return to work and functional independence.

The Functional Movement Screen^{TM} (FMS) is an assessment tool developed by Gray Cook and Lee Burton as a screening tool for fitness professionals such as physical therapists and athletic trainers to gather objective data on human movement patterns during the performance of functional activities for injury prevention. It is also widely used in many colleges and professional sports teams for injury prevention in athletes. Each of the testing criteria in the FMS was created to exacerbate the individual's compensatory movement patterns, allowing for easy identification by the examiner. By identifying movement flaws it is expected that fitness professionals can assist individuals by preventing eventual breakdown and trauma during activity.[12] One study by Hoover et al[13] found that the FMS' specificity for injury prediction was 97.2% in a sample of 49 recreational runners training for a half-marathon.

The FMS consists of 7 fundamental movement tests to identify abnormal movement patterns and impaired mobility and stability. The 7 testing categories consist of a deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg-raise, trunk stability push-up, and rotary stability. Scoring is performed on a 0 to 3 point system. A score of zero is given if the individual has pain at any point during the movement; a 1 is given if the individual is unable to be complete the activity even with compensations; a 2 is given if the individual is able to perform the movement but uses poor mechanics or compensatory methods; and a 3 is given if the individual can perform the movement without any compensations.[12] Three of the tests: shoulder mobility, trunk stability push-up, and rotary stability have clearing tests associated with them that are pass/fail to determine if the actual FMS tests in these sections is

safe to perform. For example, the clearing test for the trunk stability push up test is a prone press up. If the press up elicits pain in the individual, a score of zero is given for that section of the screen the trunk stability push up test is not attempted.

Corrective exercises were also developed as a supplement to the FMS. The corrective exercises are based on dysfunction in the dynamic motor learning, mobility and movement, stability and static exercise categories. The exercises then coordinate to specific movement dysfunction that the individual displays during the testing scenarios. The corrective exercises developed to accompany the FMS are based on incorporating proprioceptive neuromuscular facilitation (PNF) and motor learning.[14,15] At this time there is no research available to support these corrective exercises however PNF and motor learning are both well established and accepted principles for rehabilitation.

PNF exercises were developed to enhance the body's neuromuscular response through stimulating proprioceptors in the joint. PNF movement patterns are performed on a diagonal and often have a spiral component. The usage of PNF patterns has been suggested to allow muscle strengthening in functional movements patterns such as those found in sports and daily activities.[16] Kofotolis et al[16] utilized both static and dynamic PNF exercise programs in women with chronic low back pain. Finding that both methods of PNF training were highly effective in decreasing back pain, improving trunk musculature strength and endurance and decreasing disability as measured by the Oswestry disability index. PNF exercises are also widely used in rehabilitative programs in both the upper and lower extremities in addition to the trunk and have been demonstrated to be an effective method of strengthening and gaining flexibility.[17,18]

Motor learning is defined as "a set of processes associated with practice or experience leading to relatively permanent changes in the capability for producing skilled action."[19, Pg 22] It is the necessary process that allows individuals to learn new skills and improve the smoothness and accuracy of movements.[19] Physical therapists routinely utilize the theory of motor learning for rehabilitative treatment. Through the utilization of practice and intensity, the hallmarks of successful motor learning, physical therapists enable patients to produce motor patterns that are beyond their current capabilities.[20] The use of practice and intensity during training periods has been demonstrated to improve motor learning in individuals learning or relearning a task. Training that emphasizes these principles has been demonstrated to improve the quality of motor learning and reproducibility of the skill in future practice sessions and improve outcomes in both children and adults.[21]

At this time there is no research available to determine the appropriateness of the FMS corrective exercises in the rehabilitative setting. Therefore, the purpose of this case report was to determine if the FMS corrective exercises are useful in increasing trunk strength and stability, flexibility, ADL's and functional activities in a person post L5-S1 lumbar discectomy.

Case Description

The individual in this case study was a 55 year old female department of transportation laborer. Her job entails driving machinery such as a snow plow, heavy lifting, sitting and twisting at the trunk. She initially injured her low back while shoveling dirt from a washout at work on May 1, 2004. After this injury her symptoms resolved, in that she was able to return to work and athletic/recreational activities. The medical management to treat her back pain at this time is unknown. She had a second injury on March 26, 2009 when

seated bending over to tie her boot at work. Shortly after her injury she was seen by her chiropractor who recommended she see a local orthopedic surgeon. She had an MRI which was positive for a herniated nucleus pulposis at the L5-S1 intervertebral disc. She was then admitted to the hospital for pain reduction several days prior to surgery, where she was treated with morphine. The L5-S1 lumbar discectomy was performed on April 20, 2009. She rated her pain as a 10/10 on the verbal analogue scale up until after the surgery was performed. The participant reported constant pain located down the posterior aspect of her right lower extremity extending to her foot. After the L5-S1 discectomy she was treated in the hospital by a physical therapist until she was discharged at which time she returned home with a home exercise program.

She presented to outpatient physical therapy for an evaluation and strengthening program after referral from her orthopedic surgeon. At the initial interview she rated her low back pain as a 0-1/10 according to the verbal analogue scale. Her low back was "sore" in nature, with constant numbness in her posterior thigh, leg, lateral foot and heel. At the initial evaluation she reported no bowel or bladder dysfunction. She was independent in activities of daily living (ADL) including self care and driving, however she was unable to perform other tasks such as cleaning her home, walking, hiking, hunting, camping and competitive archery. She had limitations in sitting, bending, trunk rotation, and lifting as depicted in table 1. Her goals for physical therapy treatment were to return to work, and activities of daily living unrestricted and without symptoms.

Upon physical examination, she had limited trunk range of motion (ROM) in all directions most notably rotation to the right. See Table 2 for specific measurements. Manual muscle testing was performed according to the method determined by Hislop.[22] She exhibited

muscle strength deficits bilaterally with increased deficits noted in her right lower extremity. See Table 3 for specific measurements.

She presented with impaired light touch sensation at her L4-S1 dermatomes and her Achilles deep tendon reflex was impaired. See Table 4 for specific measurements. Special testing demonstrated a positive straight leg raise and short sitting slump test on the right. The aforementioned special tests were used to assess neural tension, and functional strength that is frequently affected in those having undergone discectomy. See Table 5 for specific measurements. She also demonstrated deficits in functional testing. See Table 6 for specifics. Joint mobility was then tested showing bilaterally decreased anterior hip and lumbo-sacral joint mobility. Her flexibility testing demonstrated bilateral restriction of the iliopsoas, piriformis, hamstrings and gastrocnemius. See Table 7 for specific measurements.

Outcome Measures

Manual muscle testing was employed using the "break test" method in positions against gravity as described by Daniel and Worthingham.[22] Gross ROM was performed by observing her stand with feet shoulder width apart and instructing her to rotate side to side as much as possible without twisting her hips, side bend bilaterally as much as possible, forward flex at the trunk to reach her toes and then extend backwards as much as possible. She was instructed that she should not move past the point where pain is induced. The slump test was performed with the procedure described by Maitland.[23] Active straight leg raises were performed as described by Cook.[24] The Functional squat was also performed where instructions were given to keep feet shoulder width apart and to squat down as far as she can.

For reliability and validity of the testing of all outcome measures, see Table 8. Reliability and validity was not available for the single leg stance balance test however, Lin

et al[25] performed a study in which it was determined that a shorter stance time for the single leg stance was significant in predicting a decline in ADL's however it did not significantly predict the occurrence of falls in elderly adults.

Evaluation

Based on the information gathered at the initial evaluation session, it was determined that the participant presented to physical therapy with residual numbness and myotomal weakness in her right leg affecting the L4-S2 nerve root consistent with her post surgical status. Her limitations in sitting were caused by increased neural tension and decreased flexibility. Limitations in bending, trunk rotation, transfers, lifting and ADL's and independent activities of daily living (IADL's) were due to increased neural tension, weakness, decreased flexibility and limited ROM. Her heel and toe walks were also impaired due to weakness and balance deficits. Her impairments limited her in ADL's, pain free mobility and vocational activities. It was determined that she would benefit from physical therapy treatment to restore her functional mobility.

According to the *Guide to Physical Therapist Practice*[26] the appropriate Primary Preferred Practice Pattern was 4F: Impaired joint mobility, motor function, muscle performance, range of motion, and reflex integrity associated with spinal disorders. The physical therapy diagnosis for this individual corresponds with a diagnosis of intervertebral disc disorder with myelopathy and postsurgical status, ICD-9 codes 722.7 and V45.89 respectively. The prognosis was determined to be good with expected return to work, activities of daily living and functional mobility consistent with prior level of function within a 1 year time period from the date or surgery, with significant improvement in function and

activities of daily living to occur within 3-4 months. Return to work is not typically expected until 10 months to 1 year after surgery.

The short term physical therapy goals for this individual were to (1) Improve flexibility and neural mobility from moderate-severely restricted to mildly to moderately restricted (2) Improve myotomal strength of right LE by 1/3 grade (3) Restore functional squatting, bending and twisting for light housework. Each of these goals was to be attained within 4 to 6 weeks.

The long term physical therapy goals for this individual were to (1) Improve sciatic nerve mobility and general flexibility to allow for asymptomatic tolerance of prolonged sitting for 1-2 hours to allow for return to work (2) Improve trunk strength 4- to 4/5 for being able to tolerate prolonged sitting for 1-2 hours for return to work and restore ADL's for vacuuming and light lifting (3) Achieve an ADL functional status to meet occupational requirements such as trunk twisting, reaching overhead, reaching below the waist, forward bending, squatting, crouching, sustained forward bending and driving vehicles such as a forklift or plow. Each of these goals was to be attained within 11 weeks. The frequency of physical therapy treatment was 3 times per week for a total of 11 weeks. Criterion for discharge was completion of the long term physical therapy goals, which were to return to ADL's, and go to a gym for return to work preparation.

Interventions used during physical therapy treatment of this individual were musculoskeletal re-education, stretching, therapeutic exercise, cryotherapy, manual therapy, mobilization techniques of the joints, soft tissue and neural tissue, strength training, balance exercises, range of motion exercises, and home exercise program (HEP). These were given to

address the functional limitations and impairments of this individual. See Table 9 for the specific exercises performed and Table 10 for the progression of exercises.

Additionally the purpose of each intervention is listed in Table 9. Some of the exercises listed in Table 9 are specific corrective exercises from the FMS, and variations of certain FMS corrective exercises were also included in her intervention program. The purpose of the variations were to decrease the difficulty of an exercise to make it appropriate for the specific needs of the individual being treated. For specifics on FMS based exercises see Table 11.

Outcomes

Significant improvements were noted in functional activities, range of motion, muscle strength, flexibility, and special and functional testing. All measures were not taken at discharge (ROM, strength, neurological testing and flexibility) however there was a re-evaluation which occurred approximately one month after beginning physical therapy treatment.

At discharge the individual in this case rated her low back pain as 0-1/10 according to the verbal analogue scale, which is the same rating that she provided at her initial evaluation. At her initial evaluation she was unable to perform tasks such as cleaning her home, walking, hiking, hunting, camping and competitive archery. At discharge she was able to perform all of the aforementioned activities. She had increased tolerance for sitting, standing, walking, bending, trunk rotation, vacuuming, sleeping and lifting as depicted in Table 12.

Upon her re-evaluation 4 weeks after starting physical therapy treatment, trunk ROM improved to 70-95% of normal whereas at her initial evaluation it was 25-50% of normal. She made significant improvements in strength at the one month re-evaluation although she

still exhibited some muscle strength deficits especially in her right lower extremity. At re-evaluation she presented with impaired light touch sensation in only the S1 dermatome as well as some hypersensitivity at the L4-L5 dermatomes which was positive for numbness at the initial evaluation. Her Achilles deep tendon reflexes were unchanged from initial evaluation. At discharge special testing demonstrated a positive straight leg raise; at 75º improving from the initial evaluation which was positive at 45º. The short sitting slump test did not aggravate symptoms until 80-85º at discharge where at initial evaluation it was positive at 45º. At discharge she demonstrated an unchanged toe walk on the right, and a bilaterally normal heel walk. See Tables 13-16 for specific measurements.

At discharge she demonstrated improved results in functional testing particularly in balance, the squat test, heel walking, and transfers. See Table 17 for specifics. At re-evaluation joint mobility was improved however still slightly decreased from normal at her anterior hip and lumbo-sacral joint mobility. Her flexibility testing at re-evaluation demonstrated improved flexibility particularly in her iliopsoas and piriformis. See Table 18 for specific measurements. All physical therapy goals were achieved except she was unable to return to work.

Discussion

This case report has shown how a restorative exercise program utilizing components of the corrective exercises for the FMS was used in a 55 year old female laborer status post L5-S1 discectomy for repair of a herniated nucleus pulposis. The individual in this case demonstrated improvements in ADL's, strength, range of motion, flexibility, special tests and functional testing. The improvements in testing seen in this individual are likely due to a progressive and frequently updated exercise program. Additionally the individual in this case

was extremely dedicated to the therapeutic process and was compliant in every aspect of treatment including her HEP.

Her Achilles tendon DTR remained absent at the completion of physical therapy treatment. It is possible this may not return. A study by Astrand et al[27] observed that 2 years post surgery Achilles tendon DTR's were absent in 35% the status post discectomy. Additionally Astrand et al[27] also found that 40% of individuals had impaired sensation 2 years post operatively.[27] The individual in this case report did not have an improvement in toe walking prior to discharge Astrand et al[27] also found that 11% of patients had decreased planterflexor strength 2 years after undergoing lumbar discectomy.

Although her verbal analogue pain scale rating remained consistent from her initial evaluation to discharge, she was able to greatly increase her activity without increasing her pain. She was able to tolerate ADL's which she was unable to perform at the initial evaluation such as outdoors walking, lengthy sitting and standing, bending at the trunk, trunk rotation, lifting, vacuuming and archery before experiencing the same level of pain.

The individual in this case demonstrated improvements in flexibility of her bilateral illiopsoas, piriformis, and left hamstrings and gastrocnemius due to a progressive and strategic stretching program addressing limited muscle groups. Improvements in flexibility allowed her to improve ADL's by increasing her ability to squat, ambulate greater distances and sit in a chair for longer periods of time with less pain.

Additionally improvements in strength of her abdominals, and bilateral lower extremities was due to a strategic and comprehensive strengthening program which was frequently progressed to decrease plateau effects. Several of the corrective exercises were adapted slightly so that they were appropriate for the functional level of the individual and

progressed appropriately. The FMS corrective exercises that were utilized in the rehabilitation of this individual aided in improving her balance and functional abilities through strategic and functional strengthening of the above mentioned muscle groups which demonstrated limitations at initial evaluation. The FMS corrective exercises utilized are dynamic in nature and require the individual performing them to improve their muscle stability and balance to allow them to perform the dynamic and functional components of the exercises. This aided in her improvements in performance of ADL's and functional testing as well as beginning a return to her previous functional status.

The individual in this case was able to return to nearly all ADL's and functional activities however she was unable to return to work at the completion of physical therapy treatment. This occurred due to the physically demanding nature of her occupation as a department of transportation laborer. She was unable to meet the occupational requirements of her job such as trunk twisting, reaching overhead, reaching below the waist, forward bending, squatting, crouching, sustained forward bending and driving vehicles such as a forklift or plow. She was able to perform many of the above mentioned occupational requirements for the completion of ADL's however she was still unable to perform several of these activities in the occupational context. This is due to the additional physical requirements of her occupation beyond those for ADL completion. For example, one occupational duty is that she has to sit on the back of a moving truck and put out road cones. In order to do this she would have to rotate at her trunk across her body and place the road cones on the road requiring her to have the flexibility to reach below her feet while carrying an object weighing greater than 5 lbs. This action would then need to be completed repetitively. Several other activities such as squatting, bending forward and reaching

overhead would also have to be completed while lifting potentially heavy equipment. At discharge from physical therapy she was able to transition to utilizing a home exercise program at a local gym to further increase her strength until she was able to return to work.

This case report had several limitations. Re-evaluation testing was not performed every 30 days resulting in several measures not being collected immediately prior to discharge. Additionally the corrective exercises of the FMS were not exclusively used with this individual limiting the ability to determine a direct correlation between the efficacy of the FMS corrective exercises in the treatment of an individual status post L5-S1 discectomy. Additionally, a cause and effect relationship cannot be inferred due to this study not having a large sample size without the presence of a control group.

Several of the outcome measures utilized demonstrate low sensitivity, specificity or have no research available on reliability and validity. The straight leg raise test has a sensitivity of .78-.98 and varied report of specificity throughout research of this test of .11-.84. These values indicate that the straight leg raise is better at ruling in pathology than ruling it out. The short sitting slump test has a specificity of .55, which is relatively low.[24] The statistics on reliability and validity of the functional squat were based on a study where the participants had knee osteoarthritis, not lumbar discectomy limiting its value in this case report. Additionally, there was no available research on the reliability or validity of gross observational trunk ROM.

Other tests and measures may have been more appropriate for use in this case. The FMS was also not utilized as an outcome measure in this case report due to the researcher being unaware of its existence until after the treatment was already initiated. However the FMS would have been a useful outcome measure to correlate the FMS corrective exercises

with progress made in outcomes as the FMS is entirely functionally based and correlates to the high level of functional ability needed for the individual to return to work.

Use of the EquiTest System may have been more useful than the single leg balance screen. The EquiTest System consists of a support surface with sensors at the corners below the surface and a visual surround. The EquiTest device performs a sensory organization test (SOT) with six conditions which provides a useful objective measure for identifying balance deficits for individuals with real world high level balance requirements.[28]

Additionally, a back range of motion (BROM) instrument would have provided more precise ROM measurements than use of gross ROM. The BROM is used to measure lumbar spine active planar motions. A study by Kachingwe et al[29] demonstrated that intrarater reliability is good for side bending (ICC=.85), lumbar forward flexion and pelvic inclination was (ICC=.84) and extension and rotation was (ICC=.76).

The findings of this case report support that the corrective exercises of the FMS may be helpful in the rehabilitation of this individual status post L5-S1 discectomy. Further experimental research is needed utilizing the corrective exercises to determine the efficacy and usefulness of the FMS corrective exercises in the physical therapy setting.

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Table 1: Activities of Daily Living at Initial Evaluation	
Activity	Tolerance
Sitting	Aggravates symptoms with duration = 1 hour
Standing	> 1 hour without symptom aggravation
Bending	Unable to perform
Trunk rotation	Unable to perform
Vacuuming	Unable to perform
Lifting	Tolerates lifting up to 5 lbs
Sleeping	Able to sleep on affected side

Table 2: Trunk Range of Motion at Initial Evaluation	
Flexion	40% of normal with pain
Extension	50% of normal
L Rotation	50% of normal
R Rotation	25% of normal
L Sidebending	50% of normal
R Sidebending	50% of normal

Table 3: Muscle Strength at Initial Evaluation			
Spinal Innervation	Muscle Group	Left	Right
L1-L2	Hip flexion	4-/5	4-/5
L3	Knee extension	4+/5	4+/5
L4	ankle dorsiflexion	5-/5	4/5
L5	Great toe extension	4/5	3+/5
S1	Ankle plantarflexion	4+/5	3/5
S2	Knee flexion	5-/5	3+/5
L4-L5	Hip extension	4/5	4/5
L4-S1	Hip abducton	4+/5	4/5
T4-L3	Abdominals	3/5	3/5

Table 4: Neurologic Testing at Initial Evaluation		
Test	Left	Right
Light Touch	Normal	Positive Numbness L4-S1
Achilles DTR	2+	0

Table 5: Special Testing at Initial Evaluation		
Test	Left	Right
Straight Leg Raise	Negative	Positive at 45^{o}
Short Sitting Slump	Negative	Positive at 45^{o}
Heel Walk	Normal	Weak
Toe Walk	Normal	Weak

Table 6: Functional Testing at Initial Evaluation		
Test	Left	Right
Squat	Approximately 50% of normal with left shift	
Single Leg Balance	15 seconds	15 seconds
Heel Walk	Normal	Weak
Toe Walk	Normal	Weak
Rolling transfer	Guarded but proper technique	
Sit to supine transfer	Guarded but proper technique	

Table 7: Flexibility at Initial Evaluation		
Muscle	Left	Right
Iliopsoas	Moderate Restriction	Moderate Restriction
Piriformis >90^{o}	Slight Restriction	Moderate Restriction
Hamstring	Moderate Restriction	Mild Restriction
Gastrocnemius	Mild Restriction	Mild Restriction

Table 8: Reliability and Validity of Special Tests					
Test	Validity	Inter-rater Reliability	Test Retest Reliability	Sensitivity	Specificity
Manual Muscle Testing	N/A	.97	.98	N/A	N/A
Range of Motion via observation	N/A	N/A	N/A	N/A	N/A
Straight Leg Raise	N/A	N/A	N/A	0.78-0.98	0.11-0.84
Short Sitting Slump	N/A	N/A	N/A	0.83	0.55
*Functional Squat	N/A	.92 in pts with knee OA	N/A	.23	.86

Table 9: Physical Therapy Intervention Program		
Exercise Name	Description of Exercise	Purpose of exercise
Slump Slider	Position of the short slump test where patient performs a self neural mobilization by extending their leg to the point of tension and then releasing	Neural tension along sciatic tract
Slump Tensioner	Same as slump slider however patient keeps head flexed down	Neural tension along sciatic tract
Isometric Abdominal Bracing	Lay in supine hooklying position keeping a neutral spine patient is verbally cued to "bring their belly button into their spine" and hold the contraction	Abdominal strength
Lower Trunk rotation	Supine hooklying position pt. then allows both knees to fall to one side and then the other	Trunk flexibility
Upper Body Ergometer (standing)	Pt. stands and pedals the hand crank forward for a period of time and then backwards	Trunk mobility and strength
Supine Hamstring Stretch	Pt. lays supine with hip and knee at 90-90 position the pt. then extends knee until a gentle stretch is felt	Flexibility
Bridging	Pt. lays supine in hooklying, braces abdominals and then lifts buttocks off the table so that their trunk and knees are a straight line	LE and trunk strength and stability
Functional Squat	Standing with feet shoulder width apart a belt is tied around the pt.'s thighs to prevent compensation and the pt. squats as low as they can up to 90degrees	LE and trunk strength, flexibility and balance
Retro Treadmill Walking	Backwards walking on a level treadmill	Strength of gluteal and hip extensors
Piriformis Stretch	Pt. lays in supine hooklying position and brings one ankle across the other knee making a figure four appearance then the pt. places their hand on the lateral portion of the elevated thigh and pulls the knee to their opposite shoulder until a gentle stretch is felt	Flexibility
Manual Therapy	Supine piriformis stretch, sciatic nerve mobilization, sideling illiopsoas stretch	Flexibility and neural mobility
Cryotherapy	Ice pack applied in supine with hips and knees propped up into a 90-90	Pain and inflammation reduction
Isometric Abdominal Bracing with Marching	Same as above with alternating hip flexion with instruction to maintain a neutral and unmoving pelvis	Abdominal strength

Table 9: Continued		
Quadruped Opposite Arm and Leg Lift	In quadruped position the pt. lifts their opposite arm and leg off the table maintaining a neutral spine and abdominal isometric contraction	Strength and stability
Standing Rectus Femoris Stretch	Standing with 1 foot up on an elevated surface, height to the pt.'s tolerance, and an anterior pelvic tilt is performed until the pt. feels a gentle stretch in the elevated leg	Flexibility
Posterior Reach	Pt. performs a backward lunge with posteriorly moving foot sliding on a towel	LE and trunk strength and balance
Half Kneel Chop	Pt. is in half kneeling position and performs a PNF chop pattern with theraband	Strength and balance
Anterior Lunges	From standing pt. steps one foot forward and drops hips down toward the floor in available ROM	LE and trunk strength and balance
Bow Shooting	Pt. in half kneeling with one arm flexed to 90 degrees and the other behind using theraband as resistance and performing a bow and arrow shooting motion with the posterior hand	Strength and balance
Sagital Anatomical Plane (SAP)	Standing facing away from a wall with one foot on a small stool the pt. crosses their arms across their chest and performs trunk extension towards the wall	Balance and strength
Quadratus Lumborum Sidelying Modified	Pt. lays on side with knees bent and bottom arm bent with elbow and forearm in contact with the table, the patient then lifts their trunk and hips up so they are in a straight position and then holds for a period of time	Strength and stability
Half Kneel Trunk Rotation with a medicine ball	In half kneeling position pt. holds a medicine ball in bilateral hands with shoulders flexed to 90 degrees and elbows extended then they rotate at the trunk to the side of the elevated knee without pelvic rotation	Strength and balance

Table 9: Continued		
Overhead Reach Added to Anterior Lunges	Same as above with bilateral arm lift into forward flexion to full shoulder range of motion	Strength, flexibility and balance
Lunge Matrix	Anterior lunge with overhead reach, lateral and posterior lunges	Strength, flexibility and balance
Prone Ball Opposite Arm and Leg lift	Prone over a physioball with opposite arm and leg lift maintaining a neutral and stabilized spine and trunk	Strength, stability and balance
Standing Hamstring Stretch	Pt. stands with one foot placed on a stool with knee extended pt. then forward flexes at the hip until a gentle stretch is felt	Flexibility
Toe Touch FAP and SAP	Progressed to toe touching without foot on stool	Balance and strength
Quadruped Opposite Arm and Leg Lift with stick	Same as above with addition of dowel rod between shoulders and buttocks to maintain neutral spine position and trunk stability	Strength and stability
Single Leg Balance with Chop	Pt. stands on a single leg while performing the PNF chopping pattern using theraband for resistance	Strength and balance
Single Leg Balance with Trunk Rotation	Pt. stands on a single leg with the elevated leg held at a 90-90 position with bilateral arms extended into 90 degrees of flexion pt. rotates at the trunk to the side of the elevated leg keeping pelvis neutral	Strength and balance
Bridge with Leg Lift and Core Activation	Pt. lays in supine hooklying position and extends one knee out while performing a bridge and lifting the opposite arm into shoulder flexion	Strength, stability, and balance
Bridge with Ball and LE Flexion/Extension	Bilateral feet on a physioball pt. performs a bridge then flexes the knees up while feet remain on ball and then extends knees back to original position	Strength and stability
FAP and SAP	Altered to single leg balance	Balance and strength
Cybex Functional Squat	Altered to use Cybex cable machine with a bar held at the shoulders	Strength
Bridge with Ball and LE Flexion/Extension Sustained	Altered to sustained bridge with LE flexion/extension	Strength and stability
Ball Bridge Sit	Pt. sits on a physioball with hands over chest and walks their legs out until their shoulders only remain on the ball and they are in a bridge position then they walk their body back up until they are in the start of exercise position	Strength

Table 9: Continued		
Latisimus Dorsi Pull Down	Using a Cybex machine the pt. sits facing the machine using a pulldown bar the patient reaches overhead and grabs the bar. They then pull the bar down towards the sternoclavicular notch and then brings hands back up overhead	Strength
Frontal Anatomical Plane (FAP)	Standing next to a wall with the foot nearest the wall up on a small stool the pt. crosses their arms across their chest and performs a lateral bend at the trunk towards the wall	Balance and strength
Modified Plank	Pt. in prone on a table propped on elbows with knees bent, pt. then lifts hips so that trunk and lower extremities are aligned then the position is held	Stability and strength
Figure Skater	Single leg stance with pt. holding a dowel rod to their shoulders and buttocks then the patient forward flexes at the hip maintaining contact with the dowel rod and extends one leg posteriorly keeping the knee straight	Strength, flexibility and balance
Aquatic Lateral Walking	Laterally walking from one end of the pool to the other	Strength
Aquatic Circle walking	Walk in a circle in pool until a current is produced then turn around and switch directions walking in the other direction	Strength
Aquatic Diagonal Leg kicks	Stand on one leg and with leg extended perform diagonal kicks in diagonals into D1 flexion and extension and hip abduction starting with leg maximally adducted	Strength and balance
Aquatic Noodle Sword Fighting	With both hands below the water surface the pt. has a noodle sword fight using trunk rotation	Strength and trunk ROM
Aquatic Supine Snow angels	Pt. floats on her back in the pool and makes snow angles	Strength
Aquatic Squat and lift	Pt. squats in the pool and performs a PNF lift while extending the lower extremities and rotating at the trunk	Strength, ROM and balance

Table 10: Exercise Progression											
Exercise	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11
Slump Slider	*, HEP	*, HEP	*, HEP	*, HEP	*, HEP	*, HEP	*, HEP				
Slump Tensioner								*, HEP	*, HEP	*, HEP	*, HEP
Isometric Abdominal Bracing	*, HEP										
Lower Trunk Rotation	*, HEP	*, HEP	*, HEP	HEP	HEP	HEP	HEP	HEP	HEP	HEP	HEP
Standing Upper Body Ergometer	*	*	*	*	*	*	*	*	*	*	
Supine Hamstring Stretch	*, HEP	*, HEP	*, HEP	HEP	HEP						
Bridging	*	*	*, HEP	HEP	HEP						
Functional Squat	*	*	*	*	*	*	*, HEP	HEP	HEP	HEP	HEP
Retro Treadmill Walking	*	*	*	*	*	*	*	*	*	*	*
Piriformis Stretch	*, HEP	*, HEP	*, HEP	HEP	HEP	HEP	HEP	HEP			
Manual Therapy	*	*	*	*	*	*	*	*	*	*	*
Cryotherapy	*	*	*	*	*	*	*	*	*	*	*
Isometric Abdominal Bracing with Marching		*, HEP	*, HEP	HEP	HEP	HEP	HEP	HEP	HEP	HEP	HEP
FAP		*	*	*	*	*					
Quadruped Opposite Arm and Leg Lift			*	*	*	*					
Standing Rectus Femoris Stretch			*	*	*	*	HEP	HEP	HEP	HEP	HEP
Posterior Reach			*	*	*						
Posterior Lunge						*					
Half Kneel Chop			*	*	*	*					
Anterior Lunge			*	*	*						
Bow Shooting				*	*	*	*			*	
SAP				*	*	*					
Quadratus Lumborum Sidelying Modified				*	*	*	*	*	*	*	*
Half Kneel Trunk Rotation with Medicine Ball				*	*	*					
Modified Plank						*	*	*	*	*	*

Table 10: Continued											
Figure Skater						*	*	*	*	*	*
Anterior Lunge with Overhead Reach						*	*	*	*	*	*
Lunge Matrix							*	*	*	*	*
Prone Ball Opposite Arm and Leg Lift						*	*	*	*	*	*
Standing Hamstring Stretch						*, HEP	*, HEP	*, HEP	*, HEP	*, HEP	*, HEP
Toe Touch SAP							*	*			
Quadruped Opposite Arm and Leg Lift with Stick							*, HEP	*, HEP	*, HEP	*, HEP	*, HEP
Single Leg Balance with Chop							*	*	*	*	*
Single Leg Balance with Trunk Rotation							*	*	*	*	*
Bridge with Leg Lift and Core Activation							*, HEP	*, HEP	*	*	*
Bridge with Ball and LE Flexion/Extension							*, HEP	*, HEP	*, HEP	HEP	HEP
Single Leg FAP							*	*	*	*	*
Single Leg SAP										*	*
Bridge with Ball and LE Flexion/Extension Sustained										*	*
Cybex Functional Squat								*	*	*	*
Ball Bridge Sit									*	*	*
Latisimus Dorsi Pull Down											*
Aquatic Lateral Walking								HEP	HEP	HEP	HEP
Aquatic Circle walking								HEP	HEP	HEP	HEP
Aquatic Diagonal Leg kicks								HEP	HEP	HEP	HEP
Aquatic Noodle Sword Fighting								HEP	HEP	HEP	HEP
Aquatic Supine Snow angels								HEP	HEP	HEP	HEP
Aquatic Squat and Lift								HEP	HEP	HEP	HEP

* Indicates an exercise being performed during PT interventions, HEP indicates an exercise in the home exercise program and a blank box indicates the discontinuation of the exercise

Table 11: FMS Corrective Exercises	
FMS Exercise	Corresponding exercise
Resisted quadruped diagonals neutral spine	Quadruped opposite arm and leg lift and with stick
Single leg dead lift	Figure skater, same as FMS activity but with dowel to improve spinal positioning
Overhead deep squat	Cybex squat, pt. was unable to perform deep squat activity was performed in available range
Single leg bridge with core activation	Same as described
Half kneel chop	Same as described
Backward lunge	Posterior lunge performed without resistance bands for patient level
Split stance chop	Difficulty increased to single leg balance
Ball roll with core activation	Difficulty increased by adding bridge
Squat stance lift	Aquatic squat and lift same as FMS activity however in the aquatic environment and without a theraband

Table 12: Activities of Daily Living at Discharge vs Initial Evaluation		
Activity	Tolerance at Initial Evaluation	Tolerance at Discharge
Sitting	Aggravates symptoms with duration = 1 hour	Able to tolerate duration = 2 hours
Standing	> 1 hour without symptom aggravation	> 2 hours without symptom aggravation
Walking	Unable to perform	3 Miles per day
Bending	Unable to perform	Avoids but able to perform
Trunk Rotation	Unable to perform	Avoids but able to perform
Vacuuming	Unable to perform	Able to perform
Lifting	Tolerates lifting up to 5 lbs	Tolerates lifting light objects
Sleeping	Able to Sleep on affected side	Able to sleep on affected side

Table 13: Trunk Range of Motion at 1st Re-evaluation vs Initial Evaluation		
Motion	Range of Motion at Initial Evaluation	Range of Motion at 1st Re-evaluation
Flexion	40% of normal with pain	75% of normal with pain at end range
Extension	50% of normal	70% of normal
L Rotation	50% of normal	80% of normal
R Rotation	25% of normal	80% of normal
L Sidebending	50% of normal	95% of normal
R Sidebending	50% of normal	95% of normal

Table 14: Muscle Strength at 1st Re-evaluation vs Initial Evaluation					
Spinal Innervation	Muscle Group	Left at Initial Evaluation	Right at Initial Evaluation	Left at 1st Re-evaluation	Right at 1st Re-evaluation
L1-L2	Hip Flexion	4-/5	4-/5	5-/5	4+/5
L3	Knee Extension	4+/5	4+/5	5/5	5-/5
L4	Ankle Dorsiflexion	5-/5	4/5	5/5	4+/5
L5	Great Toe Extension	4/5	3+/5	5-/5	4+/5
S1	Ankle Plantarflexion	4+/5	3/5	5/5	4+/5
S2	Knee Flexion	5-/5	3+/5	5/5	4+/5
L4-L5	Hip Extension	4/5	4/5	5-/5	4+/5
L4-S1	Hip Abducton	4+/5	4/5	5/5	5-/5
T4-L3	Abdominals	3/5	3/5	4/5	4/5

Table 15: Neurologic Testing at 1st Re-evaluation vs Initial Evaluation				
Test	Left at Initial Evaluation	Right at Initial Evaluation	Left at 1st Re-evaluation	Right at 1st Re-evaluation
Light Touch	Normal	Positive Numbness L4-S1	Normal	Positive Numbness S1, Hypersensitivity L4-L5
Achilles DTR	2+	0	2+	0

Table 16: Special Testing at Discharge vs Initial Evaluation				
Test	Left at Initial Evaluation	Right at Initial Evaluation	Left at Discharge	Right at Discharge
Straight Leg Raise	Negative	Positive at 45^{o}	Negative	Positive at 75^{o}
Short Sitting Slump	Negative	Positive at 45^{o}	Negative	Positive at 80-85^{o}
Heel Walk	Normal	Weak	Normal	Normal
Toe Walk	Normal	Weak	Normal	Weak

Table 17: Functional Testing at Discharge vs Initial Evaluation				
Test	Left at Initial Evaluation	Right at Initial Evaluation	Left at Discharge	Right at Discharge
Squat	Approximately 50% of normal with left shift		Approximately 70% of normal with slight left shift	
Single Leg Balance	15 seconds	15 seconds	> 30 seconds with good trunk control	30 seconds with poor trunk control
Heel Walk	Normal	Weak	Normal	Normal
Toe Walk	Normal	Weak	Normal	Weak
Rolling Transfer	Guarded but proper technique		Slightly guarded but proper technique	
Sit to Supine Transfer	Guarded but proper technique		Slightly guarded but proper technique	

Table 18: Flexibility at 1st Re-evaluation vs Initial Evaluation				
Muscle	Left at Initial Evaluation	Right at Initial Evaluation	Left at 1st Re-evaluation	Right at 1st Re-evaluation
Iliopsoas	Moderate Restriction	Moderate Restriction	Slight Restriction	Mild Restriction
Piriformis >90°	Slight Restriction	Moderate Restriction	No Restriction	Mild Restriction
Hamstring	Moderate Restriction	Mild Restriction	Slight Restriction	Mild Restriction
Gastrocnemius	Mild Restriction	Mild Restriction	Slight Restriction	Mild Restriction