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Neuromuscular Electrical Stimulation And Quadriceps Strength Following Patellar Fracture And Open Reduction Internal Fixation Surgery: A Case Report

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The patient signed an informed consent allowing the use of medical information and photographs for this report and received information on the institution's policies regarding the Health Insurance Portability and Accountability Act.

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Abstract

Background and Purpose: Patellar fractures followed by open reduction internal fixation (ORIF) surgery can cause numerous impairments which can negatively impact a person's ability to participate in normal daily activities. Quadriceps weakness is common following this type of injury and surgery, and the literature reflects varying opinions as to what is the best method for regaining strength. Previous studies have examined the use of neuromuscular electrical stimulation (NMES) in conjunction with traditional exercises on quadriceps strength following surgeries such as a total knee arthroplasty (TKA), but there is limited research involving patients status post (s/p) ORIF following a comminuted patellar fracture. The purpose of this case report was to document the use of NMES in conjunction with traditional exercises for strengthening the quadriceps following atrophy s/p ORIF surgery for a comminuted patellar fracture.

Case Description: The patient in this case report was a 28 year-old female s/p left comminuted patellar fracture and ORIF surgery presenting to physical therapy (PT) with quadriceps weakness among other impairments. She was treated with NMES in addition to traditional land and aquatic quadriceps strengthening exercises approximately three times per week for three weeks.

Outcomes: The patient's quadriceps manual muscle testing (MMT) score improved from 3+/5 (slightly greater than fair) at initial examination to 4/5 (good) three weeks later.

Discussion: These findings suggest that NMES in conjunction with traditional quadriceps strengthening exercises may have had the ability to improve quadriceps strength in this individual s/p comminuted patellar fracture and ORIF surgery. Research is needed to validate the outcome of this intervention in this patient population.

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Background and Purpose

Patellar fractures account for approximately 1% of all fractures and are most common in people who are 20 to 50 years old.[1] Comminuted patellar fractures occur when the bone shatters into three or more pieces and is usually caused by a direct blow to the knee.[1] Initial symptoms include bruising, inability to straighten the leg, and inability to walk.[1] An official diagnosis is made after x-rays are taken and, if bone fragments are displaced, the patient will undergo surgery. Open reduction internal fixation (ORIF) surgery is typically needed if the bone is broken into three or more pieces near the center of the patella.[1] Recovery time for this injury varies depending on the severity and whether or not there were any complications during surgery.

Patients who endure a comminuted patellar fracture could experience decreased knee range of motion (ROM), decreased lower extremity (LE) strength, inflammation, quadriceps atrophy, decreased patellar mobility, and gait asymmetries which may cause difficulties with ambulation, stair negotiation, driving, activities of daily living (ADLs), lifting, transfers, sleeping, and/or recreational activities. Due to these impairments, activity limitations, and participation restrictions, physical therapy (PT) plays a vital role in restoring function and improving quality of life. Quadriceps strength is an important aspect of rehabilitation following this injury and surgery because it pertains to many of the limitations the patient may experience. For example, increasing quadriceps strength allows the patient to improve with ambulation, stair negotiation, and ADLs.

Following a literature review on comminuted patellar fractures status post (s/p) ORIF surgery, it was discovered that there are minimal case studies on rehabilitation after this injury and surgery. Most of the literature discusses tendon ruptures,[2] stable fractures,[3] or the studies are

outdated. Case studies have been conducted that examined the use of neuromuscular electrical stimulation (NMES) in addition to traditional exercises on quadriceps strength after other knee surgeries such as a total knee arthroplasty (TKA), for example, which showed an increase in strength.[4] Despite this, it became evident there appeared to be no case studies which specifically looked at the use of NMES in conjunction with traditional exercises for strengthening the quadriceps following an ORIF surgery after a comminuted patellar fracture, which is why this case report was needed. Therefore, the purpose of this case report was to document the use of NMES in conjunction with traditional exercises for strengthening the quadriceps following atrophy s/p ORIF surgery for a comminuted patellar fracture.

Case Description: Patient History and Systems Review

The patient signed an informed consent allowing the use of medical information, photographs, and participation in this case report. This 28 year-old female suffered a left comminuted patellar fracture during a snow skiing accident where she crashed into a tree head-on. She underwent surgery for an ORIF of her left patella approximately 12 weeks prior to her initial examination. Her most recent x-rays at the time of her initial examination, taken three weeks prior, confirmed the wires were still in place and there were no signs of malunion. The wires were scheduled to be removed one month after the initial examination. Family history included cancer in her father, but other family history was unknown. This patient was in good health aside from the injury, but did have a diagnosis of anxiety which she controlled with Adderall, Klonopin, Spironolactone, and Prozac. This patient did not demonstrate any behavioral health risks and she had a good fitness level prior to the injury.

After the injury, she was having difficulties with ambulation, stair negotiation, driving, ADLs, lifting, transfers, sleeping, and recreational activities. She had support from her mother

with whom she was living with at the time in a two-story home. The patient's goal for PT was to be able to participate in recreational activities again such as skiing, golf, and tennis. Table 1 explains the findings of the systems review. Figures 1 and 2 demonstrate the patient's physical appearance at the time of initial examination.

Clinical Impression 1

The patient's primary problem was s/p left patellar fracture and ORIF surgery which caused impairments in body structure and function, activity limitations, and participation restrictions. Since this was a specific injury followed by a surgery, the diagnosis was clear and no other differential diagnoses were expected. The plan for the initial examination was to measure ROM of the bilateral knees, perform manual muscle testing (MMT) of the bilateral LEs to determine the location of her weakness, perform circumferential measurements to evaluate for swelling or atrophy in the quadriceps or gastrocnemius muscles, check patellar mobility, ensure there were no signs of a blood clot or deep vein thrombosis (DVT), and analyze her gait pattern. It was determined that this patient was a good candidate for this case report because she met the following selection criteria: she was motivated and excited about PT, had experienced a comminuted patellar fracture and ORIF, presented with quadriceps atrophy and weakness, and her plan of care included traditional exercises in conjunction with NMES.

Examination: Tests and Measures

The psychometric properties of each test and measure used during this case report are important aspects to consider. If the tests and measures are valid and reliable, the information and procedures can be used in the future with confidence. For this case report, the Lower Extremity Functional Scale (LEFS) outcome measure was utilized from Binkley et al[5] to establish her level of function. The reliability and validity of the LEFS was assessed and research

had shown reliability was 0.98 for patients with anterior knee pain and validity was 0.86 for patients with osteoarthritis.[6] Despite differing patient populations, this outcome measure may still be a reliable and valid tool.

Regarding Homan's sign, reliability and validity values could not be found. This test is used to determine if there are signs of a blood clot or DVT in the leg, but some research suggests that it may have a poor predictive value for the presence or absence of a DVT.[7] This special test was conducted during the initial examination as per Magee's *Orthopedic Physical Assessment*.[8]

ROM measurements were performed during this case report with a standard goniometer according to Norkin and White's *Measurement of Joint Motion: A Guide to Goniometry*[9] to assess for any restrictions. A recent study published in the *Manual Therapy* journal[10] examined the reliability of assessing knee ROM with a standard universal goniometer versus a smartphone goniometric application. This study also examined the reliability of measurements between experienced clinicians and final year PT students. The authors found that both assessment methods were reliable with no significant differences between the experienced clinicians and students. Both the standard universal goniometer and the smartphone goniometric application had a reliability value of 0.98. The reliability value regarding accuracy of measurements between experienced clinicians and students was 0.96.[10]

MMT within this case report was performed as per Kendall et al[11] to assess for areas of muscle weakness. Research performed on MMT measures found that test-retest reliability was considered excellent between 0.97 and 0.98, however this was evaluated on patients with osteoarthritis.[12] There was also excellent interrater reliability at 0.94, however this may not apply to the patient in this case report because that value was specific to patients with a spinal cord injury. Many values were gathered regarding construct validity, but overall they were found to be

adequate to excellent and were also conducted by using data from patients with spinal cord injuries.[12]

A recent study published in the *Phlebology* journal[13] examined the reliability and reproducibility of repeated tape measurements to assess limb circumference during an extended period of time. They found that the short, medium, and long-term reliability measurements were 0.90, 0.80, and 0.78 respectively when multiple people took the measurements. When the same person took all of the measurements, the reliability value increased to 0.94. Validity was not measured in this study, but overall the tape measurements appeared to be a reliable and reproducible way to measure limb circumference.[13] The anthropometric measurements executed in this case report were consistent with the procedures in Magee's *Orthopedic Physical Assessment* [14] and were performed in order to evaluate for swelling or atrophy in the quadriceps or gastrocnemius muscles.

Observational gait analysis terminology from the Professional Staff Association of Rancho Los Amigos Medical Center[15] was utilized in order to define this patient's gait pattern. A study done on the reliability and validity of the Rancho Los Amigos Observational Gait Analysis found that there was moderate to substantial intrarater reliability and fair to moderate interrater reliability and concurrent validity.[16] Overall, the researchers found the Rancho Los Amigos Observational Gait Analysis to be a moderately reliable and valid tool to assess progress throughout the course of a patient's treatment.

Lastly, the numeric pain rating scale (NPRS), by McCaffery et al,[17] was used to assess this patient's level of pain. Test-retest reliability was determined to be adequate to excellent (0.63-0.92 for people with chronic pain) and concurrent validity was also determined to be excellent (0.80-0.88).[18] Many of the tests and measures that were used in this case report were

shown to be valid and reliable. Limitations are, of course, related to the fact that reliability and validity research for these tests and measures were not specifically analyzed with patients who were s/p patellar fracture and ORIF surgery. See Table 2 for outcome measures at initial examination.

Clinical Impression 2

Based on the data from the initial examination, the initial impression was confirmed and the patient demonstrated impairments in body structure and function, activity limitations, and participation restrictions due to her left patellar fracture and ORIF surgery and no additional diagnoses were found. This patient's PT diagnosis was most associated with the ICD-9 code 822.0, labeled "Fracture of Patella, Closed". At that time, she did not need further referrals or consultations, so the next plan of action was to proceed with PT interventions in order to address her limitations. Periodic re-evaluations would be performed to monitor improvements in areas such as ROM, strength, edema, atrophy, joint mobility, and gait.

This patient continued to be appropriate for this case report because she demonstrated quadriceps atrophy and weakness according to circumferential measurements and MMT done during the initial examination. She also still fit into the correct patient population for the case report since she did not have any contraindications for NMES. The plan for intervention, based on findings from the initial examination, included general strengthening exercises for the left LE in conjunction with NMES, which was the most important aspect of therapy in regards to this case report. Other interventions included ROM and stretching exercises, gait training, and aquatic therapy. Re-evaluations would be administered at least once a month in order to monitor her progress which would include the LEFS outcome measure, goniometry, MMT, circumferential measurements, gait analysis, and pain ratings using the NPRS.

Given this patient's past medical history, prior level of physical activity, family support, and self-motivation, her prognosis was determined to be good. The patient's anxiety prevented an excellent prognosis. A systematic review conducted in 2011[19] examined the effect of psychological variables on surgical recovery in 16 different studies within the PubMed, Scopus and PsycINFO databases. The authors found significant evidence that anxiety negatively affected recovery after surgery, but optimism had a significantly positive impact on recovery. Positive social support was also examined and this had neither a positive or negative effect that was clinically significant.

See Table 3 for short-term and discharge goals for PT regarding this patient.

Interventions

The PT plan of care (POC) for this patient included the coordination of land therapy with aquatic therapy to ensure both forms of interventions were targeting her needs. Coordination with PT assistants (PTAs) was also needed to ensure the POC would be followed. Communication was another important aspect of the POC and included the patient, primary care physician, orthopedic surgeon, PTs, and PTAs. Documentation for this patient's interventions and parameters were recorded on separate exercise flow sheets for land and aquatic therapy for each visit. Additionally, detailed daily notes and progress notes were written throughout her course of treatment. The patient's POC called for three visits per week for 12 weeks, but due to the timing of her wire removal, this author only saw her three times per week for three weeks.

Patient related instruction included a home exercise program (HEP) which was given on the first day (see Appendix 1). She was instructed on how to do the exercises and educated on the importance of her surgical precautions and proper gait pattern. She was also instructed to

complete strengthening exercises once per day and stretching exercises twice per day. A home electrical stimulation (e-stim) unit was ordered for her two weeks into therapy and she was educated on how e-stim should feel and how to properly use the device. Figure 3 shows the patient using the NMES unit.

After information was gathered from the initial examination, and an evaluation, diagnosis, and prognosis were completed, interventions were chosen geared towards the patient's specific needs. Given that the patient presented with decreased left knee ROM, decreased strength of the left LE, inflammation, quadriceps atrophy, decreased patellar mobility, and gait asymmetries, this author chose certain interventions to address each limitation. The patient was seen for a total of eight treatment sessions, which included five land-based sessions and three aquatic-based sessions. Her land-based therapy appointments were 30 minutes each and aquatic therapy appointments were 45 minutes each. See Appendices 2 and 3 for parameters and demonstrations of land-based interventions and Appendix 4 for a detailed explanation of aquatic-based interventions.

A knee extension stretch, heel slides, knee flexion stretch on the wall, quadriceps stretch, and hamstring stretch were chosen to gain extension and flexion ROM in the left knee. Quadriceps sets, 4-way straight leg raises, partial wall squats, step-ups, terminal knee extension, hamstring curls, heel raises, and NMES were chosen to increase strength in the left LE and decrease atrophy of the quadriceps. NMES was an important part of the POC in increasing her quadriceps strength. Aquatic exercises helped supplement the LE strength and ROM exercises performed on land. The combination of the above interventions were chosen to help decrease inflammation, increase patellar mobility and aid in improving this patient's gait pattern.

Clinical judgement was used to determine the chronology of interventions and how to progress exercises and parameters over time. Progression of strengthening exercises involved increased repetitions, increased step height, or a more difficult exercise. Stretching and ROM exercises were progressed by increasing the duration of the stretch, increasing repetitions, or performing a more difficult exercise. Exercises were discontinued when they became too easy or when they were no longer beneficial for the patient's goals.

The patient tolerated the NMES well, however she was only able to get to the sensory level of stimulation intensity on the first day. NMES was done again the next treatment session and she was able to tolerate a higher intensity for a longer time period, as well as achieve a full muscle contraction. Each day she used the e-stim, the patient got a stronger contraction and was able to start performing quadriceps sets and straight leg raises in conjunction with the e-stim to promote additional quadriceps strengthening. Throughout the duration of her treatment, this patient tolerated all of the interventions well. Therefore, no changes were made to the POC aside from the typical progression of interventions that occurred with improvement. The patient was compliant with her HEP and attended scheduled appointments while this author participated in her treatment.

A study published in the *Journal of Orthopedic & Sports Physical Therapy*[20] examined the effect of NMES on quadriceps strength and voluntary activation and found that deficits in quadriceps strength resolved quickly when NMES was added to a voluntary exercise program. Another study examined the effectiveness of quadriceps strengthening exercises on knee joint pain and found that, according to Brief Pain Inventory-Short Form (BPI-SF) scores, the intensity of knee joint pain was decreased after performing the exercises for five weeks.[21] The exercises

used in the study were heel slides, quadriceps sets, straight leg raises, and hamstring curls which were all exercises that the patient in this case report performed on a regular basis.

The *Journal of Physical Therapy Science*[22] published an article assessing the effects of home-based stretching exercises on ROM and gait speed and the authors found that ROM improved, pain decreased, and gait speed increased. The two knee flexion exercises described in the study were similar to the stretching exercises performed by the patient in this case report during her PT sessions and at home. Both exercises were knee flexion stretches that were held for 30 seconds, only one was in a sitting position and the other was in prone. Regarding this case report, they can be compared to the knee flexion stretch with the towel and the wall knee stretch.

Lastly, a systematic review, published in the *Journal of Aquatic Therapy*,[23] found evidence that aquatic PT was beneficial in reducing pain and increasing quality of life, ROM, joint extensibility, and strength. The authors also reported that water and land-based interventions used together were more effective than land-based interventions alone in treating LE injuries.

Given the information from these studies in conjunction with clinical experience, the interventions that were chosen for this patient had a good rationale and there was a positive likelihood the patient would increase her functional abilities and decrease the amount of impairments, activity limitations, and participation restrictions she had prior to treatment. Co-interventions for this patient involved any aquatic or land exercises that did not include e-stim or quadriceps strengthening (such as stretching exercises, as well as hamstring, calf, and general hip strengthening exercises).

Outcomes

At the time of initial examination, the patient presented with many impairments, activity limitations, and participation restrictions. Three weeks after initial examination, she increased left knee active ROM from lacking (-) 5˚extension and 38˚flexion to 0˚extension and 69˚ flexion. Regarding outcome measures related to the purpose of this case report, the patient's quadriceps MMT score improved from 3+/5 (slightly greater than fair) at initial examination to 4/5 (good). Circumferential measurements of the left LE also improved as she was able to reverse quadriceps atrophy and inflammation decreased. Specifically, the circumferential measurement for the left quadriceps was 41 cm upon initial examination which increased to 42 cm within three weeks. She also demonstrated fewer gait asymmetries and reported less overall pain according to the NPRS (5/10 initial, 2/10 three weeks later). Lastly, the LEFS was repeated and she reported an 18% increase in function after three weeks of PT. See Table 2 for outcome measures three weeks after initial examination.

Discussion

Overall, this case appeared to have a successful outcome given that the patient increased ROM and strength in the left LE, decreased quadriceps atrophy, improved her gait pattern and LEFS score, and decreased her overall pain level. The purpose of this case report was met as demonstrated by the increased quadriceps MMT score following strengthening exercises in conjunction with NMES. Positive factors most likely associated with the outcomes of this case report included motivation, family support, and the therapy provided. These findings suggest that NMES in conjunction with traditional quadriceps strengthening exercises may have had the ability to improve quadriceps strength in this individual s/p comminuted patellar fracture and ORIF surgery. As far as implications for future clinical practice, in conjunction with further

investigation, NMES may be beneficial in increasing quadriceps strength for patients with this type of injury and surgery.

Since this author could not locate any case reports or research relating to this specific topic, the outcomes of this case report could not be easily compared. Despite this, there were still positive outcomes with the use of NMES in this case report and this supports findings from the literature discussed previously regarding the use of NMES in conjunction with strengthening exercises in patients s/p TKA.[4] Further research is needed to validate the outcome of this intervention in patients s/p patellar fracture and ORIF surgery, as well as other patient populations.

Additional research that could be beneficial for this patient population is examining the efficacy of quadriceps strengthening exercises alone without the use of NMES. It would be interesting to see how this compares to NMES in conjunction with strengthening exercises, as was done in this case report. It would also be beneficial to examine the efficacy of common stretching exercises in regards to ROM. Findings in these areas could help address common impairments that occur as a result of a comminuted patellar fracture and ORIF surgery which could improve quality of life for this patient population.

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Tables, Figures and Appendices

Table 1. Systems Review

Cardiovascular/Pulmonary	Vital signs were not assessed at the time of the initial examination.
Musculoskeletal	Gross AROM and gross strength were impaired in the left leg. She also had significant atrophy in her left quadriceps.
Neuromuscular	Gross LE sensation was intact bilaterally.
Integumentary	The integumentary system was impaired. A scar was present on the left knee from the ORIF surgery and there was some mild bruising on the medial aspect of the knee.
Communication	Communication was intact.
Affect, Cognition, Language, Learning Style	Affect, cognition, and language were all intact. She learns best with pictures and demonstrations.

AROM= active range of motion, LE= lower extremity, ORIF= open reduction and internal fixation

Table 2. Outcome Measures at Initial Examination and 3 Weeks after Initial Examination

Tests and Measures	**Initial Examination Results**		**Re-evaluation Results: 3 Weeks after Initial Examination**	
	Left	**Right**	**Left**	**Right**
Goniometry (Knee AROM)	Lacking 5˚ extension	2˚ hyperextension	0˚extension	NT
	38˚flexion	157˚flexion	69˚flexion	NT
Lower Extremity MMT	Hip flexor: 4/5	5/5	4+/5	NT
	Quadriceps: 3+/5	5/5	4/5	NT
	HS: NT due to pain	5/5	NT	NT
	Ankle DF: 5/5	5/5	NT	NT
	Ankle PF: 5/5	5/5	NT	NT
Edema/Circumference	Mid-patella: 37 cm	34.5 cm	36 cm	NT

	5 cm above: 36.5 cm	35.5 cm	36.5 cm	NT
	15 cm above: 41 cm	43 cm	42 cm	NT
	5 cm below: 32 cm	32 cm	32 cm	NT
	15 cm below: 33 cm	32 cm	32.5 cm	NT
Lower Extremity Functional Scale	30% function bilaterally		48% function bilaterally	
Homan's Sign	Negative bilaterally		NT	
Gait Analysis	Lacked full left knee extension, decreased cadence, flat foot, decreased hip extension on the left, antalgic, left lateral lean		Full left knee extension, faster cadence, flat foot on the left, decreased hip extension the left, antalgic gait pattern	
Numeric Pain Rating Scale	3/10 today, 5/10 at worst		0/10 today, 2/10 at worst	

NT= not tested, AROM= active range of motion, LE= lower extremity, MMT= manual muscle testing, HS= hamstrings, DF= dorsiflexion, PF= plantarflexion

Table 3. Short-Term and Discharge Goals

Short-Term Goals	**Discharge Goal**
1. Patient will be able to demonstrate 0˚- 90˚ of left knee passive ROM with no complaints of pain for improved ambulation, transfers, and ADL's by 5 weeks after the initial examination.	1. Patient will be unrestricted in ambulation, stair negotiation, lifting, and recreational activities with pain less than 2/10 on a 0-10 pain scale by 12 weeks after the initial examination.
2. Patient will demonstrate at least 4/5 on all left LE MMT grades for improved stair negotiation by 5 weeks after the initial examination.	

ROM= range of motion, ADL= activities of daily living, LE= lower extremity, MMT= manual muscle testing

Figure 1. Comparison of both legs showing quadriceps atrophy on the left

Figure 2. Close up of left knee showing scar and bruising

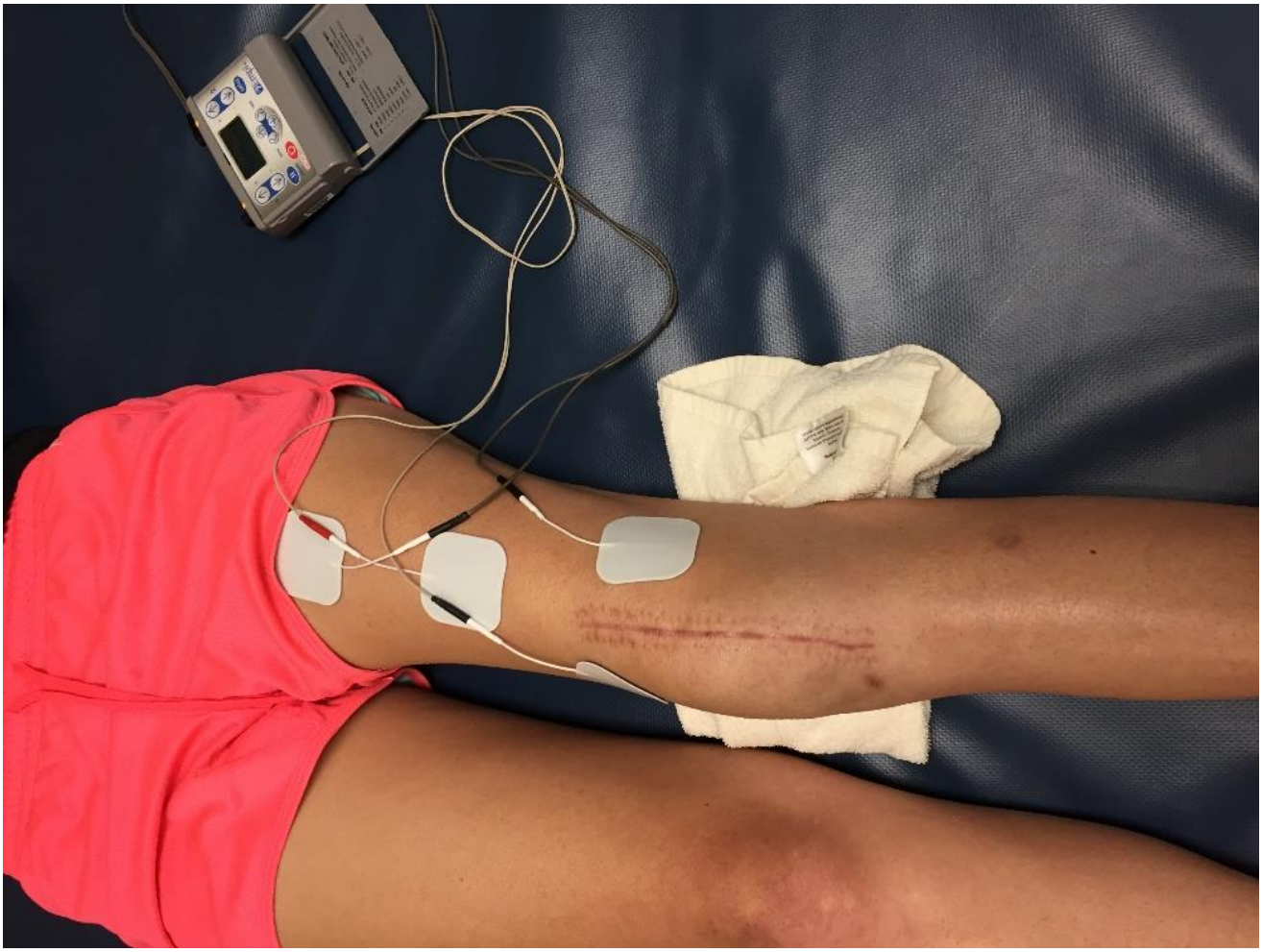
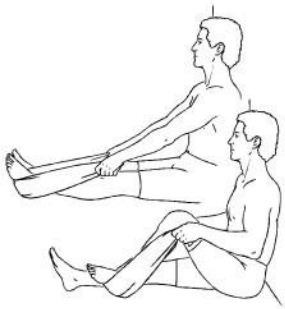
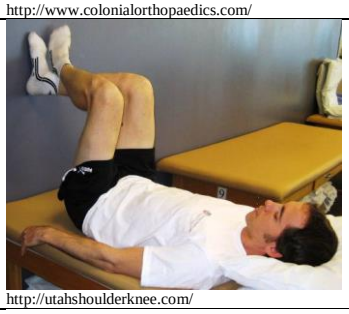
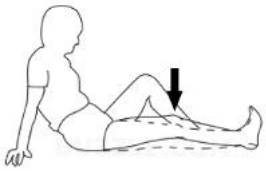
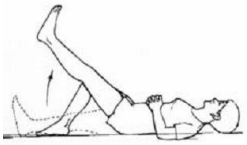
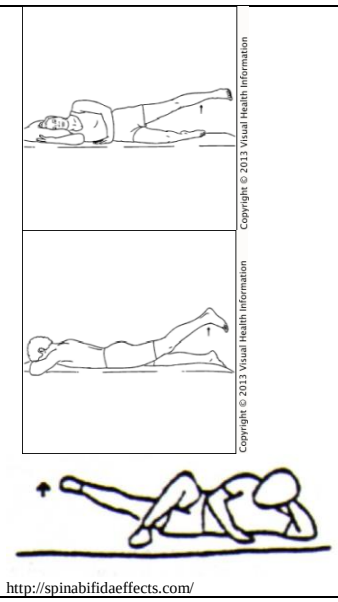


Figure 3. *Empi Continuum neuromuscular electrical stimulation and †electrode placement

*Empi Continuum Neuromuscular Electrical Stimulator: Model #9681031
Empi, Inc. a DJO company
205 Highway 22 East
Clear Lake, SD 57226
† Empi 2"x2" Self-Adhesive Premium Electrodes: Model #199658-001
EMPI Recovery Sciences
599 Cardigan Road
St. Paul, MN 55126 USA

405 **Appendix 1.** Home Exercise Program

Exercise (left side)	**Parameters**	**Demonstration**
Knee extension stretch	5 minutes, 2x/day (discontinued after 0˚ extension achieved)	 http://www.uofmhealth.org/
Knee flexion stretch with towel	3x30 seconds, 2x/day	 http://www.colonialorthopaedics.com/
Wall knee flexion stretch	3x30 seconds, 2x/day	 http://utahshoulderknee.com/
Heel slides	2x10, 1x/day	 http://www.physioprescription.com/
Quadriceps sets	2x10, 1x/day	
4-way straight leg raises	x10 each direction, 1x/day	 http://web.eccrsd.us/christy/public/

		
E-stim	Empi Continuum NMES PPR 1 x 10 minutes, 1x/day (started 2 weeks after initial examination)	See Figure 3

406 E-stim=electrical stimulation, NMES=neuromuscular electrical stimulation, PPR=pre-program

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408 **Appendix 2.** Land-Based Exercise Interventions

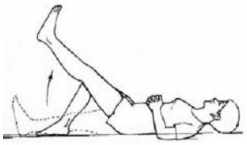
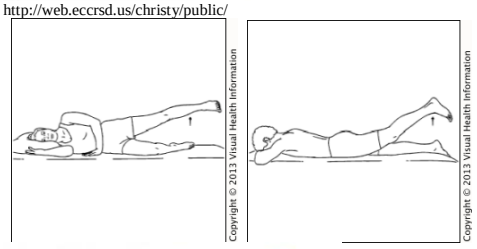
Intervention (left side)	**Week 1 (1 session)**	**Week 2 (2 sessions)**	**Week 3 (2 sessions)**
Quadriceps sets	x 10	x 10 early in the week and x 10 with e-stim later in the week	x 10 with e-stim
Knee extension stretch	5 minutes	d/c	d/c
Heel slides	x 10 and 2 x 30 seconds	x 10 and 2 x 30 seconds	x 10 and 2 x 30 seconds
Wall knee flexion stretch	2 x 30 seconds	2 x 30 seconds	2 x 30 seconds with strap
4-way straight leg raises	x 10 each	x 12 each	x 10 with e-stim early in the week and x 20 with e-stim later in the week
Partial wall squats	x 10	x 10	x 12

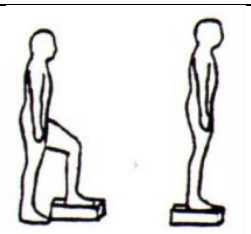
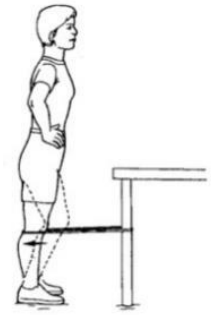
Step-ups	Not performed	4” x 10	6” x 20
Quadriceps stretch	2 x 30 seconds at stairs	d/c	d/c
Terminal knee extension	Not performed	‡With REP band (orange level) 2 x 10	d/c
Hamstring curls	Not performed	x 10	x 12
Electrical stimulation	Empi Continuum NMES PPR 1 x 10 minutes	Empi Continuum NMES PPR 1 x 10 minutes early in the week and x 20 minutes later in the week	Empi Continuum NMES PPR 1 x 20 minutes
Heel raises	Not performed	x 15	x 15

Rx= treatment, e-stim= electrical stimulation, REP= Resistive Exercise Products, NMES= neuromuscular electrical stimulation, PPR= pre-program, d/c= discontinued

‡REP Band- orange level 2: Model #03006
Magister Corporation
310 Sylvan Street
Chattanooga, TN 37405

418 **Appendix 3.** Land-Based PT Exercise Demonstrations

Exercise (left side)	**Demonstration**
Quadriceps sets	
Knee extension stretch	 http://www.uofmhealth.org/
Heel slides	 http://web.eccrsd.us/christy/public/
Wall knee flexion stretch	 http://utahshoulderknee.com/
4-way straight leg raises	 http://web.eccrsd.us/christy/public/   http://spinabifidaeffects.com/
Partial wall squats	 http://www.absoluterehabcentre.com/

Step-ups	 http://www.narrabriphysiotherapy.com
Quadriceps stretch	 http://www.preventlowbackpain.com/
Terminal knee extension with REP band (orange level)	 http://web.eccrsd.us/christy/public/
Hamstring curls	
Electrical stimulation	See Figure 3
Heel raises	

419 PT=physical therapy, REP=resistive exercise products

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Appendix 4. Aquatic-Based Exercise Interventions

Intervention	**Week 2 (2 sessions)**	**Week 3 (1 session)**
Walking forward	2 laps	2 laps
Walking backward	2 laps	2 laps
Side step	2 laps	2 laps
Side step with squat	2 laps	2 laps
High knees marching	2 laps	2 laps
Hamstring curls	2 laps	2 laps
Bicycle	1 lap	2 laps
Squats at ladder	x 10	x 12
Heel raises	x 10	x 10
Hamstring stretch	3 x 30 seconds	3 x 30 seconds
Step-ups	8” x 10	8” x 12