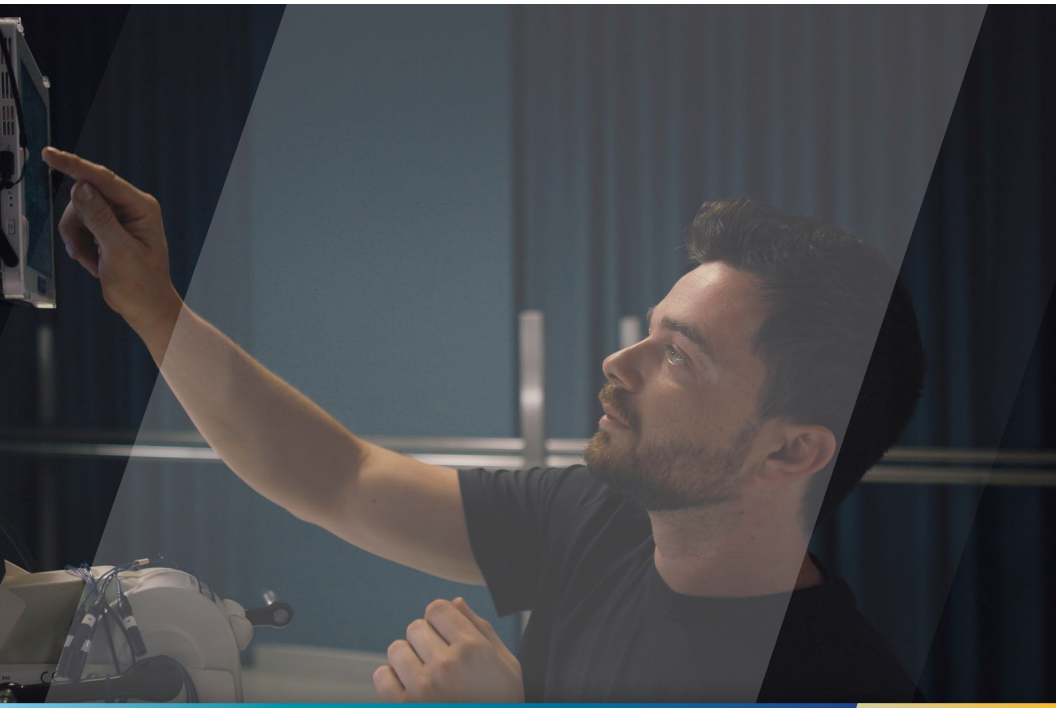

FUNCTIONAL ELECTRICAL STIMULATION CYCLING IN ACUTE CARE FOR SPINAL CORD INJURY REHABILITATION: **A TOOLKIT FOR HEALTHCARE PROVIDERS**

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FES Cycling Toolkit for Patients and Caregivers

> *"Well, I was going to take [FES cycling] as far as I possibly could. The difference between being in a wheelchair and walking in a walker is like flying to the moon. I mean, it's just so different. A lot of people I don't think realize that….And, of course, going from the walker to a cane, and then from dropping the cane, it's just each step is like going to a completely new planet. So, it is quite remarkable."*
>
> **- FES Cycling User**

DISCLAIMER

The toolkit has been specifically designed for the implementation of functional electrical stimulation (FES) cycling for spinal cord injury (SCI) rehabilitation using the RT 300 FES leg cycle at the University of Alberta Hospital and the Royal Alexandra Hospital located in Edmonton, Alberta with the expertise of multiple stakeholders. However, this toolkit may be used to inform FES cycling rehabilitation at other sites, settings, and for other conditions.

Table of Contents

1. Introduction and Rationale

AIM: To provide health care providers with easy access to evidence-based material about functional electrical stimulation (FES) cycling and the tools to inform its implementation in acute care spinal cord injury (SCI) rehabilitation.

FES cycling falls under the broad term activity-based therapy (ABT). Musselman et al. 2018 define ABT as "therapeutic activities that involve repetitive neuromuscular activation below the level of spinal injury, typically achieved through intensive, task-specific movement practice."[1]

FES cycling uses electrical impulses which stimulate and contract the muscles. As a result, cyclic movement occurs using the legs and/or arms. Earlier studies testing FES cycling for SCI rehabilitation in acute care have shown that this therapy can prevent the loss of muscle mass, increase muscle power, and decrease the rate of bone mineral density loss[2,3]. Engaging in FES cycling in the acute care phase, when the potential for neurorecovery is greatest, could be more beneficial than later implementation. FES cycling has been implemented as early as two to three weeks after the initial injury, with few complications and/or dropouts[4–6]. Importantly, individuals living with SCI would like to start activity-based therapy, for example FES cycling, as early as possible in their rehabilitation[7].

2. How can FES cycling help me?

a. Benefits[8–12]

Target area	Potential benefit from FES cycling
Cardiovascular	• Improve blood flow • Decrease glucose and insulin levels in blood • Improve and maintain cardiovascular conditioning • Increase in lean muscle mass and capillary numbers
Muscle health and movement	• Increase muscle size and strength • Improve muscle composition • Improve fatigue resistance • Improve rate of soft tissue healing • Reduce swelling • Prevent disuse atrophy
Bone health	• Prevent loss of bone mineral density • Improve bone health in lower limbs • Improve rate of fracture healing • Increase joint range of motion
Spasms and spasticity	• Reduce frequency and/or intensity of muscle spasms • Reduce effects of spasticity
Cardiometabolic	• Reduce amount of adipose tissue
Secondary complications	• Decrease chance of infections • Decrease chance of pressure injuries • Decrease chance of fractures
Other	• Increase ISNSCI* score in lower extremity • Recovery of movement below the level of the injury

International Standards for Neurological Classification of Spinal Cord Injury

b. Risks[12,13]

The potential risks of FES cycling include:

- Fatigue
- Brief drop in blood pressure
- Increased spasticity
- Light-headedness
- Skin redness
- Incontinence
- Leg swelling
- Autonomic dysreflexia
- Quadriceps hematoma
- Bone fracture

3. Patient Screening

a. Indications [2,14–27]

- Muscle atrophy
- Reduced lean body mass
- Reduced muscle cross sectional area
- Poor insulin sensitivity
- Poor glucose control
- Cardiovascular deconditioning
- Unhealthy or unfavourable adipose % or body mass index
- Loss of bone density
- Loss of lower extremity strength
- Reduced power output in lower extremities
- Presence of spasticity
- Poor quality of life
- Reduced self esteem
- Poor sense of wellbeing
- Reduced VO2 max and physical endurance
- Reduced lung health and function
- Presence of spasms

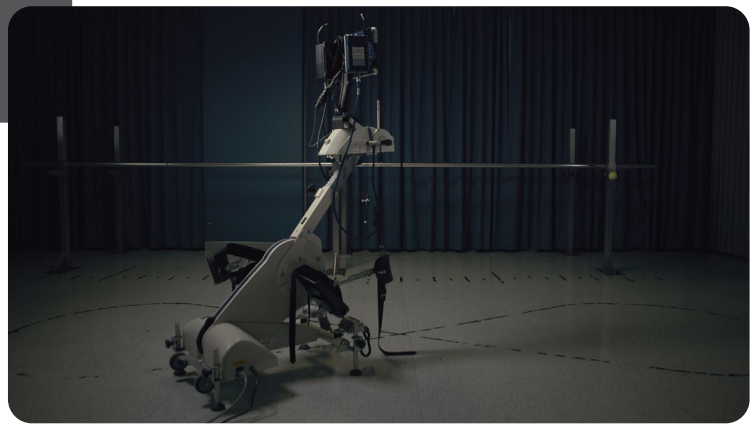
The RT 300 FES motorized cycle ergometer is classified as a Class 2 medical device by Health Canada[28]. The specific indications for the RT 300 include:

- Muscle re-education
- Prevention or delay of disuse atrophy
- Maintain or increase range of motion
- Increase local blood circulation
- Relax muscle spasms

b. Relative contraindications, absolute contraindications, and comorbidities [2,5,9,10,15,22,24,]

●	Highest risk of harm or injury
●	Moderate risk of harm or injury
●	Special Consideration
●	Lowest risk of harm or injury
◆	Comorbidities*

**Comorbidities refer to other medical conditions that may interfere with how a patients respond to FES cycling. Some of these conditions may put them at higher risk of unfavourable outcomes or may prevent them from being able to participate in the program.*



These are absolute contraindications to FES cycling ranked in order from least to most severe:

Absolute Contraindication	Description	Severity
Rotator cuff tear	• Grade 3 or greater rotator cuff tear	
Pressure ulcers in buttocks or legs	• Recent pressure injury • Pressure injury greater than grade 2 • Skin breakdown that limits the ability to sit for 30 mins	
Cardiac demand pacemaker* (if applied to thoracic wall)	• Details provided below	
Fractures	• Recent unstable fractures • Long bone or pelvic fractures • Fragility fractures • Lower limb fractures in the past 6 months	
Pregnancy	• Not been tested in pregnant women	

Proceed with Caution: Functional electrical stimulation use with patients who have a pacemaker or implantable cardiac defibrillator[40–43]

Consider having a conversation with the health care team about using FES cycling with a patient who has a pacemaker or implantable cardiac defibrillator. There is limited information that directly discusses FES use for cycling with patients with SCI who also have a pacemaker (PM). However, inferences are made about a similar treatment (TENS) and the effects on cardiac pacemakers or implantable cardiac defibrillators (ICDs).

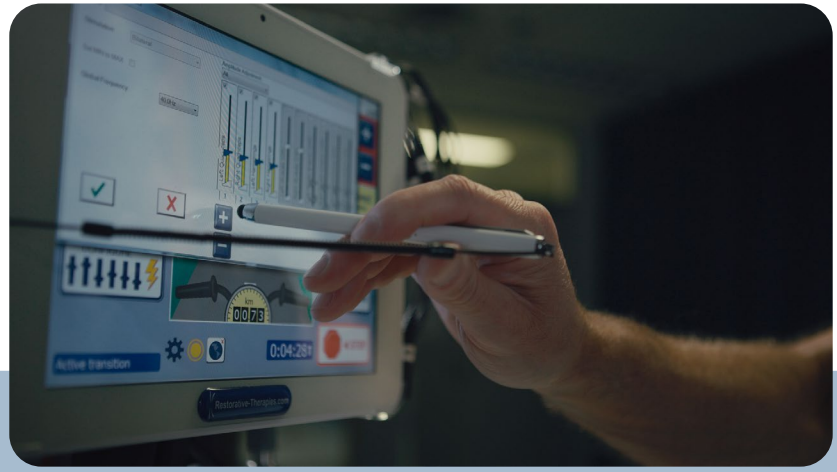
It is possible that devices that use electrical stimulation, such as TENS or FES, may interfere with a PM or ICD. This can include administering extra shocks or preventing shocks from occurring altogether. It appears that the risk is higher when the machine's electrodes are placed closer to the thoracic wall or the site of device implantation and lessens as they are placed further from this site. The settings used on the machine may also have implications on the risk associated with a PM or ICD.

These are precautions to FES cycling ranked in order from least to most harmful:

Precaution	Description	Severity
Lower motor neuron involvement	• Lower motor neuron injury • Absence of spinal reflexes • Neurological degenerative diseases • Total denervation that precludes the use of FES • Flaccid paralysis in response to FES	
Psychological/ cognitive disorder	• Cognitive difficulties or disorders • Psychological instability • Severe symptoms of depression or anxiety • Recent history of alcohol abuse for which treatment was recommended	
Active infectious disease	• Consider site of disease and severity	
Contractures	• Contractures of hip and knee preventing full ROM on bike • Less than 90 degrees flexion of hip and knees	
Heterotopic ossification	• Severe joint calcifications • Away from site of stimulation	
Metal implants	• Newly placed	

Severe pain	• Uncontrolled pain • Complex regional pain syndrome	🟢
Active epiphysis		🟢
Allergies	• Allergy to electrodes • Skin reactions to electrodes or FES	🟡
Joint instability	• History of knee subluxation or dislocation • Hip dislocation	🟡
Seizures/Epilepsy	• Seizure history • Diagnosis of epilepsy	🟡
Less severe pressure injury	• Pressure injury lower than grade 2	🟡
Diseases of bone metabolism	• Osteoporosis • Diseases or medications known to affect bone metabolism • Dual Xray absorptiometry T-score less than -2.5	🟡
Autonomic dysreflexia (AD)	• Uncontrolled or poorly controlled autonomic dysreflexia • Severe AD in response to electrical stimulation • Vasomotor instability • Frequent or severe bouts of AD	🟡
Hypertension	• Uncontrolled hypertension • Understand what constitutes high blood pressure on an individual basis for each patient, this number may vary	🟡
Regenerating nerves in the treatment area		🔴
Medications	• Chronic steroid treatment	🔴

Clotting abnormalities and prolonged bleeding times	• Full dose anticoagulation • Thrombophlebitis	🔴
Endocrinopathies	• Severe diabetes • Uncontrolled hyperglycemia or HbA1c >%7 • Untreated thyroid disease	🔴
Malignancy	• Lower limb malignancy • T6 and below spinal malignancy • Consult with oncologist	🔴
Cardiovascular disease	• Chronic arterial disease • Unstable cardiovascular disease • Uncontrolled arrhythmia • Angina • Congestive heart failure	🔴
Thrombosis	• Recent, untreated venous thromboembolism (within past 3 months) • Current deep vein thrombosis or pulmonary embolism	🔴



4. Dosage parameters, muscle selection, and outcome measures

a. Dosage parameters and progression

Although there are default settings that are common to use when starting patients on FES cycling programs (see table below), it is important to recognize that pain, apprehension, and other factors related to the injury may limit stimulation amplitudes and duration6. The progression of stimulation should be highly individualized especially in the first 3 months post-injury. It is appropriate to increase amplitudes in small increments from session to session especially in the first 4 weeks if patients do not experience problems such as pain, discomfort, increased spasticity, or issues in blood pressure regulation during or after FES cycling. In general, as they progress further into the program, patients require less frequent (every 3-5 sessions) increases in stimulation.

It is also important to note that patients may not be able to produce contractions strong enough to cycle with zero resistance, therefore motor support should be used to cycle with muscle stimulation continuing at maximally tolerated level without producing undue discomfort or fatigue. The parameters below are suggestions only, they can be adjusted according to your own clinical judgment.

Suggested parameters for functional electrical stimulation cycling[6]

Parameter	Example first session	Example progression (10 weeks)
Pulse width (μs)	300	300
Frequency (Hz)	40	40
Cadence (rpm)	20	40
Duration (minutes)	15	45
Number of sessions per week	3	3

Suggested intensity according to muscle group for functional electrical stimulation cycling[6]

Intensity	Example first session	Example progression (10 weeks)
Quadriceps (mA)	25	100
Hamstrings (mA)	30	80
Gluteals (mA)	35	100
Gastrocnemius (mA)	50	60

**It is also suggested to evaluate the strength of the muscle contraction and to determine whether the individual has sensation*

> *"The effects of cycling usually lasted two, sometimes three, days after the cycling. [The] legs were more limber, [and] spasms were not so aggressive. I think it improved overall health afterwards. And the longer in between sessions, [limbs] would get stiff, and [the] spasms [would] be more aggressive and harder to control, so [I've] definitely seen that benefit there."*

– FES Cycling User

b. Muscle selection

Depending on the individual's goals and muscle capabilities, various muscle groups can be stimulated during FES cycling. However, it is common to always stimulate quadriceps and hamstrings, and combine these with gluteals and/or gastrocnemius.



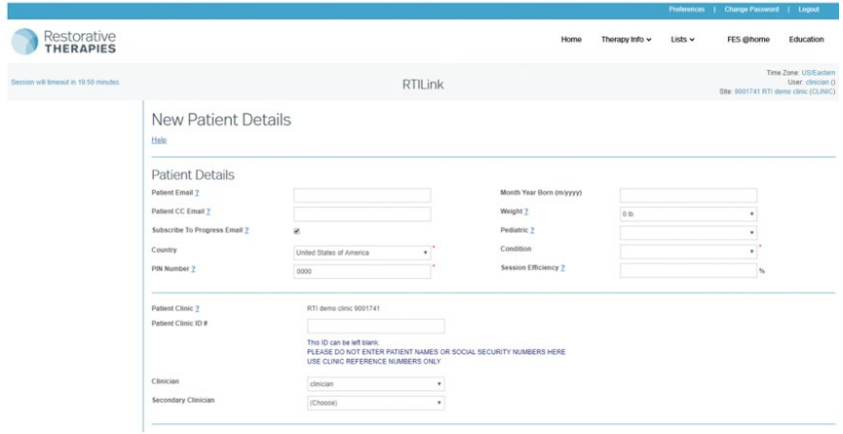


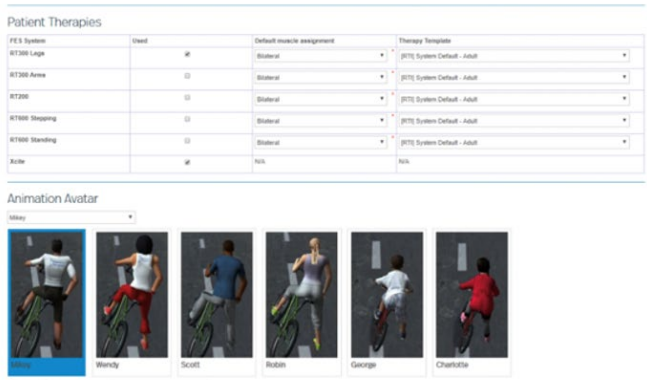
c. Outcome measures

Outcome measures recorded by the program: Average asymmetry, distance traveled, energy per hour (kCal), energy expended (kCal), average stimulation, power, speed, average pulse and peak pulse.

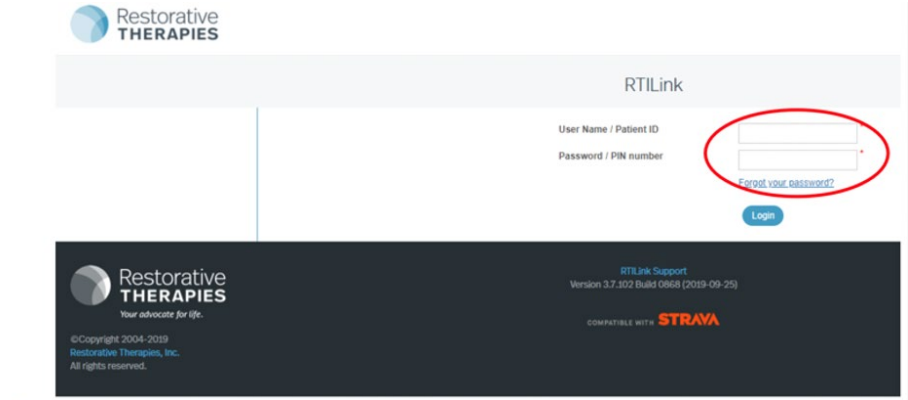
5. Bike Login, Setup, and Modifications

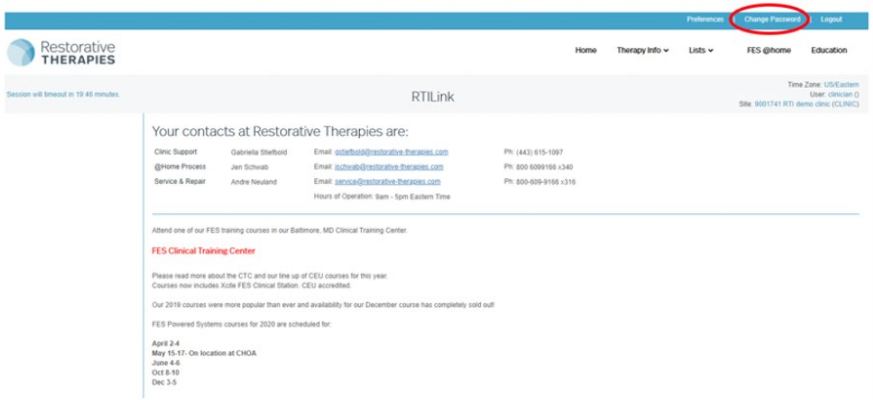
a. Creating a new patient ID - https://www.rtilink.com



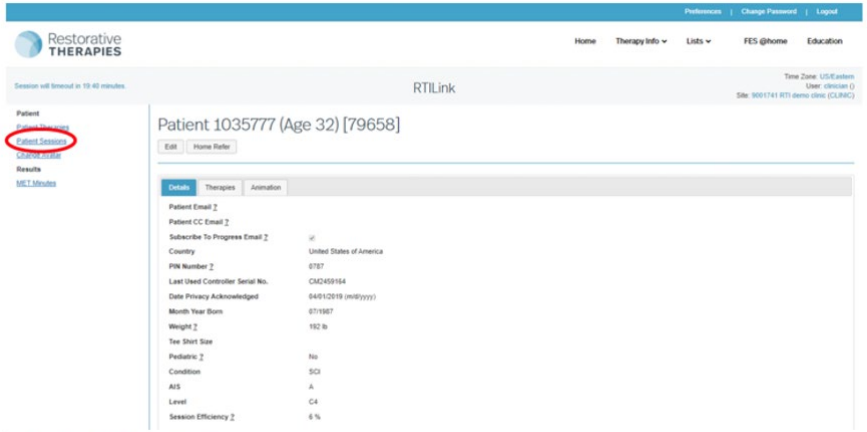


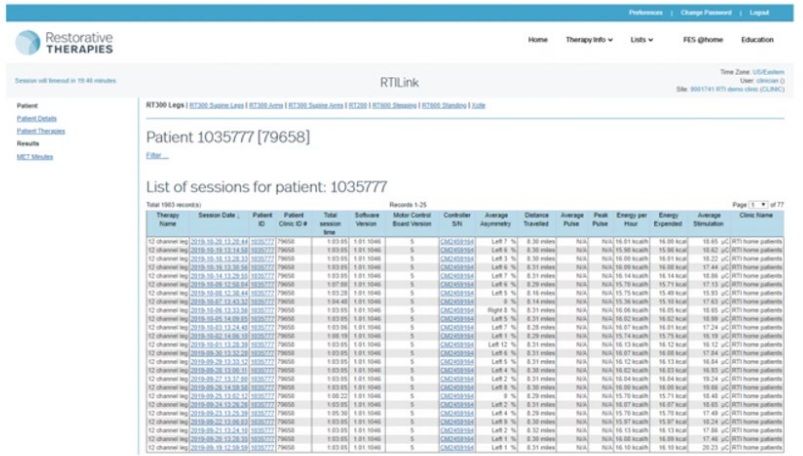
b. Login and logout procedures - https://www.rtilink.com/datalink/login.htm





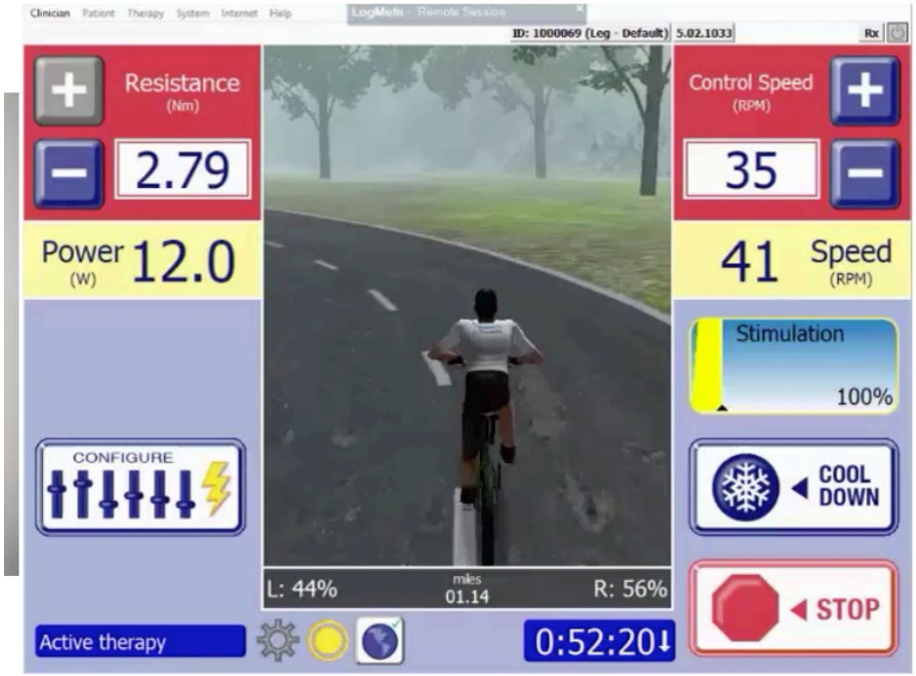
c. Patient details and session information



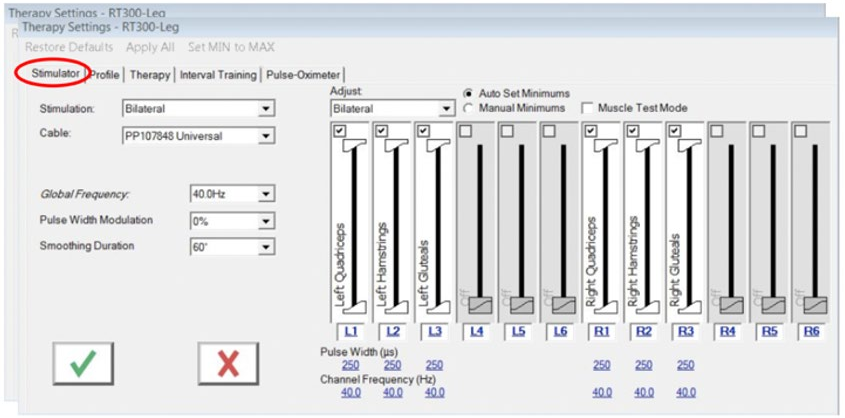


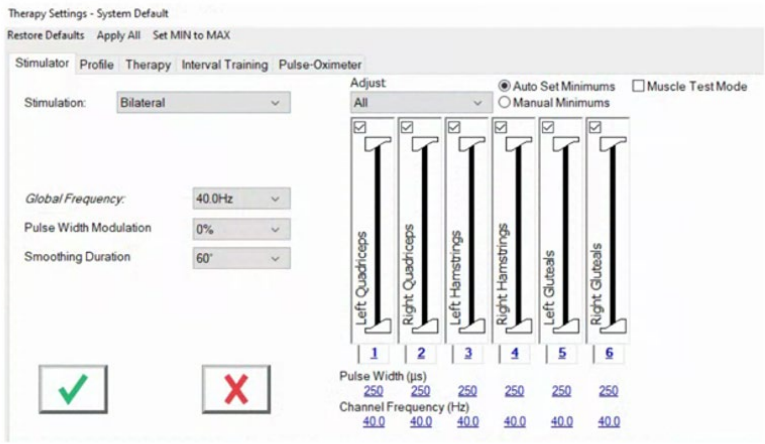
d. Configure settings

The stimulation settings can be configured directly on the FES cycle screen along with other cycling parameters (speed, resistance).



i. Default leg stimulation parameters





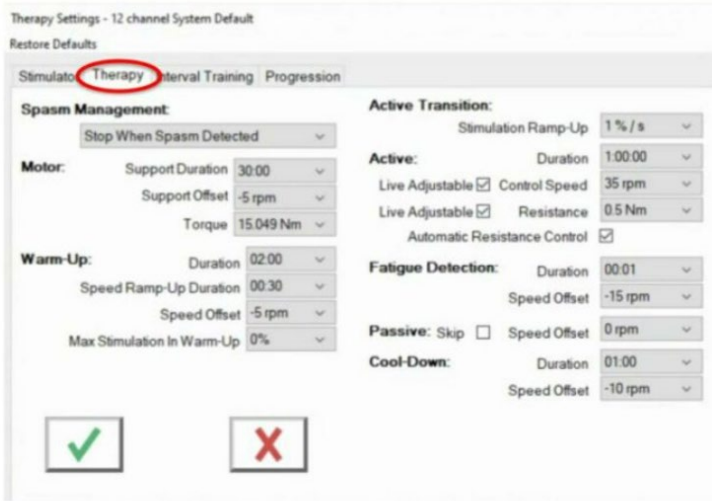
ii. Setting minimum stimulation values

No Volition

- Patient is unable to volitionally move the pedals
- Set mins = 0mA
  - The amount of charge necessary for the workload is delivered

Volition

- Patient can volitionally move the pedals
  - Could be using compensatory patterns, hip flexors/ abdominals, etc.
- Therapeutic dosage of FES is delivered regardless of crank speed



e. Physical Set-up for acute care

Physical Set-Up

"So to me the sooner you start the better. I mean I could see in the first, you know, 2 months, how quick my legs are shrinking away and I was cycling. So, if you can cycle do it."

- FES Cycling User

6. Before, During, and After Functional Electrical Stimulation Cycling

a. Before the FES cycling session

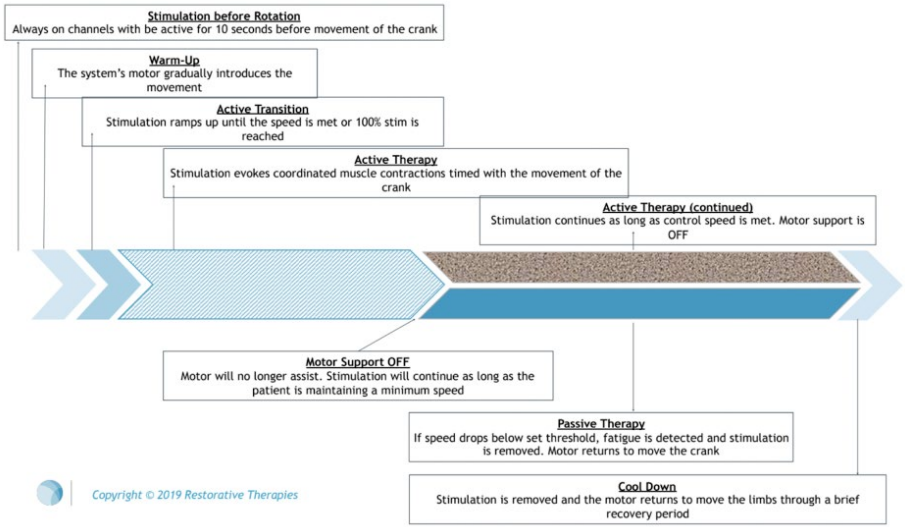
Nursing team checklist

- Check patient's whiteboard to see if FES cycling session is scheduled for that day.
- Ensure vitals/medical status of patient is appropriate to leave unit prior to appointment time (i.e., after pain meds).
- Ensure meal eaten (i.e., breakfast or lunch), adequate hydration ahead of time.
  - 60-90 minutes prior to prevent gastrointestinal distress, nausea, and/or vomiting)
- Pain/other medications (i.e., gabapentin, baclofen, etc..) given at appropriate time.
  - 15-30 mins prior to session.
- AM care/hygiene (brush teeth, shower, shave, dressing into clothing).
- Don abdominal binder if needed.
- Don orthotics/braces if needed.
- Toileting routine (catheterization, bowel routine)
- Change soiled clothing/brief
- Transfer up to seating system/wheelchair (based on rehabilitation recommendations/assessment) (e.g., Medi-lift)
- Ensure other appointments (if possible) are scheduled with sufficient time around this appointment (i.e., X-rays, imaging, labs) – if urgent appointment needed, communicate with rehabilitation staff.

Rehabilitation team checklist:

- Full assessment – history, vital signs, appropriate ROM of upper and lower extremities to use the FES cycle
- Clarify any contraindications and precautions with the healthcare team for electrical stimulation (e.g., weight-bearing status for fracture, wounds, grafting, wound vac, new tracheotomy, high respiratory status)
- Determine appropriateness/medical stability
- Tolerance for session time (i.e., 1 hour of sitting upright in wheelchair they will be using for the session)
- Check to see if wheelchair and cushion are appropriate for FES cycling
- Confirm appointment time with nursing day of session (i.e., AM), on patient's whiteboard
- Make computer login ID for patient*
- Appropriate outcome measures (ROM, Muscle circumference, MMT) *first session only

b. During the FES cycling session



Rehabilitation team checklist

- ☐ Monitor rate of perceived exertion
- ☐ Monitor vitals throughout treatment session (pre/during/post vitals)
- ☐ Monitor for signs and symptoms of autonomic dysreflexia

Tips for a successful FES cycling session

- Keep a close eye on the patient. Don't leave them to bike on their own for 45 minutes.
- Make sure the electrodes don't peel off. Check the electrodes regularly, pat down edges that have lifted, or apply tape.
- Make sure the patient's feet stay in the pedals, check regularly and put their feet back when they slide forward.
- Add resistance if the patient doesn't use 100% of the stimulation levels that you set (depending on how you choose to do the progressions).
- If patients bike volitionally, check their speed regularly, they could be doing 50 RPM when their goal is 35 RPM (depending on how controlled you want the sessions to be).

Autonomic Dysreflexia Event

- Turn off stimulation
- Sit the patient upright
- Loosen up clothes including abdominal binder and stockings
- Check the foley catheter to make sure foley is not kinked
- Check skin
- Monitor the vital signs every 2-5 min
- If it is not resolved, notify the most responsible physician (MRP) and there should be a medication ordered in the chart.

Code Event·

- If code event is called, the health care team will come to the rehabilitation space for patient care
- Let the unit know where the patient is using the FES bike
- To call CODE BLUE dial the appropriate number for your hospital

c. After the FES cycling session

Nursing and Rehabilitation Team

- Check the skin under the electrodes. Note skin redness that does not go away ~ 1-2 hours after session
- Monitor vitals every 30-60 minutes in case of autonomic dysreflexia
- May need toileting/brief change
- May need extra hydration/nutrition
- May want or need to change out of “exercise clothes”
- May want range of motion exercises
- Transfer back to bed to rest (if patient requests)
- Offer breakthrough pain meds if needed

Documentation

Using the smart phrase below, or the drop-down menu located under RT300, you can document the parameters in your clinical notes.

RT300 {Arm/Leg:27413} Cycle Settings:

ID: ***
PIN: ***
{RIGHT LEFT BILATERAL:24854}
Global Frequency: 40 Hz
Global Pulse Width: 250 µs

Channel	Muscle Stimulated	Amplitude(mA)	Pulse Width
L1			Global
L2			Global
L3			Global
L4			Global
L5			Global
L6			Global
R1			Global
R2			Global
R3			Global
R4			Global
R5			Global
R6			Global

Warm up: *** minutes
Active cycling (backwards/forwards): *** minutes/*** minutes
Cool down: *** minutes
Resistance: *** Nm
Control Speed: *** rpm
Motor: *** Nm
Goals: ***

7. Sustainable practice and transitions in care

a. Onboarding new team members

To be determined by staff at the site at this time.

b. Electrode ordering and selection

A complete set of electrodes for leg cycling involves a total of 10 muscles, with 5 muscles per leg, requiring 20 electrodes in total. Typically, 3×4" electrodes are employed for all leg muscles, with the 2×3.5" electrodes used for the tibialis anterior in a few cases. Opting for a single electrode size is more convenient. One set of electrodes is designed to last a minimum of one month and can extend to two months or more, depending on variables such as skin type and the amount of body hair present.

For bulk hospital orders, purchase 8 to 16 packages of 20 elecrodes. Individual patients should purchase either 1 or 2 packs of 20 electrodes.

c. Vendor information

Axelgaard PALS electrodes for electric stimulation can be purchased from

- Atlas medic
- Amazon.ca
- Performance Health

d. Community resources

FES Community Options - Greater Edmonton Area

Saville Centre	Steadward Centre	YMCA - Castledowns	YMCA - Don Wheaton
Location: South Edmonton	Location: South Edmonton	Location: North Edmonton	Location: Downtown
Carly Frenkel carly.frenkel@ualberta.ca 780-492-7114	Allison Hunder infotsc@ualberta.ca 780-492-8339	Jasmyne Pedersen jasmyne.pedersen@ymcanab.ca 780-377-3720	Allison Piper allison.piper@ymcanab.ca 780-969-8946

FES Assessment - Please note that if you DO NOT have a current FES program already developed, you will need an FES assessment to build an FES bike program specific to you and your needs. Cost of this 2-hour assessment is $153.

FES Site	Cost	Baseline Level of Support	Scheduling	Extra Site Info
Saville Centre*	$18/month	- Machine set-up - Tensor wrapping - Connect pre-placed electrodes - Onsite storage of supplies	- Open Google Calendar or call 780-492-1701 - Book appointments up to 1 week in advance	- Saville fitness centre is located on 2nd floor, if low mobility we suggest a support person
Steadward Centre	2x/week = ~$175-$275 / 4 months 3x/week = ~$250-$400 / 4 months	- Full set-up and take-down support - Onsite storage of supplies	- Participant commits to a consistent schedule for 4 months at a time, 2x or 3x/week	- Electrodes available onsite for purchase - FES includes access to all other gym equipment
YMCA - Castledowns*	18-64 yr = $33 biweekly 65+ yr = $28 biweekly Plus = $58.75 biweekly	- Onsite storage of supplies	- Drop-in	- Financial assistance may be available
YMCA - Don Wheaton*	18-64 yr = $33 biweekly 65+ yr = $28 biweekly Plus = $58.75 biweekly	- Onsite storage of supplies	- Drop-in	- Financial assistance may be available

*** For Saville and YMCA sites, first year of fees (FES Assessment, FES riding fees, electrodes) will be covered by SCITCS for individuals with Spinal Cord Injury**

Glossary

Amplitude: refers to the intensity or strength of the current being delivered. The amplitude setting controls the amount of current delivered to the nerves and muscles and can be perceived as gentle tingling to more intense electrical sensations.

Frequency (Channel): measured in Hertz (Hz). It is the number of stimulation pulses delivered per second by one channel.

Frequency (Global): measured in Hertz (Hz). It is the number of stimulation pulses delivered per second by all channels.

Grade 3 rotator cuff tear: more than ½ th thickness of rotator cuff tear (Ellman classification)

Power: force times velocity that the rider is putting on the FES cycle pedals. It is measured in watts (W).

Pulse width: length of time that each electrical pulse is delivered. It is measured in microseconds (µs) or milliseconds (ms).

Watt: rate of energy production.

> *"Oh, I attend the gym every week at the [community centre]. So, the FES cycling and the gym at the [community centre] is all in the same facility so, I try to gym and then cycle. I try to go at least 3 times a week."*
>
> **- FES Cycling User**

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