

Functional Electrical Stimulation (FES)

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Functional electrical stimulation is a treatment that activates muscles below the spinal cord injury (SCI) during exercise and activity. This page outlines basic information about functional electrical stimulation and its use for movement and strength after SCI.

Key points

- Electrical stimulation can be used to activate muscles that are weak or paralyzed after an SCI.
- Functional electrical stimulation (FES) involves stimulating the muscles during an activity like exercise or movement.
- FES is relatively safe and widely available treatment option for improving muscle strength and fitness after SCI.
- Overall, the research evidence suggests that FES is most likely effective for improving muscle strength after SCI. It may also improve fitness, walking skills, bone density and other symptoms, although more high quality research is needed to confirm.

What is 'functional electrical stimulation' (FES)?

Functional electrical stimulation (or *FES*) is a type of *neuromodulation* where electrical stimulation is applied to the nerves located outside the spinal cord and brain. This stimulation causes the muscles to contract and can assist with purposeful or functional movement in weak or paralyzed muscles.

FES is delivered using a variety of handheld or specialized commercial electrical therapy machines connected to electrodes that are placed on the skin surface. Systems are also available with implanted electrodes in the muscles, although this is very specialized and not widely available.



FES electrodes are placed on the leg muscles to be used during stationary cycling.¹

Muscle stimulation is used for several reasons after SCI:

- To promote movement and strength in weak or paralyzed muscles
Muscles stimulation is used early in rehabilitation to promote movement in muscles that are not moving or only producing a flicker of movement. It may promote recovery of movement function by assisting with normal movements and with repetition of movements.
- To improve fitness and health
When FES is used as part of a rhythmic exercise like cycling, walking, or rowing, it can help to maintain health of the heart, lungs, and circulation. It may also help to maintain healthy bones.

- To assist with functional movement activities like stepping, getting up to standing, and grasping
FES can be used to assist with purposeful movements by improving muscle contractions (for weakened muscles), mobility or range of movement as well as possibly decreasing spasticity.
- To maintain muscle mass below the SCI
Regular use of FES may help to prevent muscle loss that happens when the muscles that are paralyzed are not used. Unless neurological return occurs this improvement will stop if the FES is discontinued.
- To control the muscles of breathing and bladder function
This includes the use of surgically implanted *diaphragmatic* pacers (FES systems that create muscle contractions in the diaphragm to stimulate regular breaths) and bladder control systems (FES systems that stimulate the muscles of urination). However, this page will focus on FES used for movement and strength after SCI.

Other names for FES

You may hear other names for FES such as ‘neuromuscular electrical stimulation’ (NMES) or simply ‘electrical stimulation’. These terms are often used to refer to electrical stimulation of the muscles during more passive activities (like lying down or sitting). ‘FES’ usually describes stimulation during *purposeful* activities like cycling or walking. However, in practice these terms are often used interchangeably to describe similar or related treatments and the goals of all are to promote strength, movement and function and to decrease pain and spasticity.

There are a number of other neuromodulation techniques that are used for various purposes in SCI, including [transcutaneous electrical nerve stimulation](#), [sacral nerve stimulation](#), and [intrathecal Baclofen](#), described in other SCIRE Community articles.

Click on the links to the left for articles on other types of neuro-modulation!



How is FES done?

It is important to speak with a health provider about using FES to make sure it is safe and suitable for you and to learn how to use the equipment correctly.

FES is usually applied through electrodes that are placed on the surface of the skin, although electrodes can also be implanted into the muscles. Electrodes are placed over nerves or part of the muscles below the SCI that respond well to electrical stimulation. The electrodes are then attached to an adjustable machine that generates the stimulation. Your health provider will determine the settings that are used for the treatment and how long it will last for.

The electrical stimulation is then gradually turned up until the muscles begin to tense or contract. Depending on your sensation, as the machine is turned up, you may feel pins and needles or other unusual sensations, which may take some time to get used to. The aim is to create a forceful but tolerable muscle contraction.

If the electrical stimulation goes well, it is then combined with a movement task. This may be as simple as lifting a wrist or ankle or more complex such as cycling on a stationary bike, rowing on a rowing machine, grasping, or stepping in parallel bars or a body weight support treadmill system.



FES is applied through electrodes on the leg muscles during assisted walking²

The length of each session will vary depending on the goals of the treatment. Time may be required to enable your muscles to tolerate longer sessions as the muscles may fatigue quickly. Sessions are usually done several times per week for several weeks to gain training benefits.

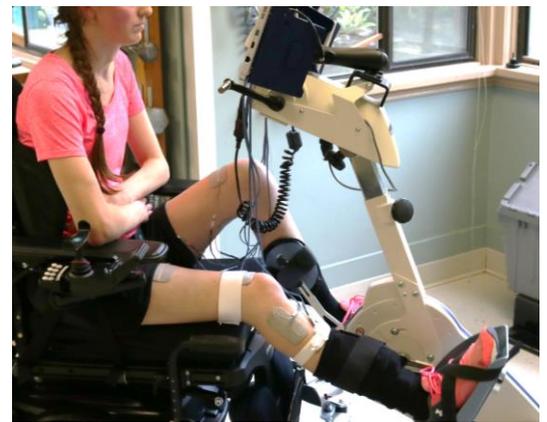
Your health provider will monitor your response to the treatment and inspect the skin for any redness or irritation after the treatment has ended. Once you have learned to use FES safely, you may be able to use it on your own.

How does FES work?

Our bodies naturally use electrical signals as part of the nervous system. When we move, the brain generates and sends electrical impulses along the spinal cord and nerves to tell the muscles to move.

Spinal cord injury can interrupt this pathway, preventing electrical impulses from passing through the spinal cord to reach the muscles. However, if the nerves and muscles below the injury are not damaged, they can still respond to electrical signals.

FES electrodes are placed over nerves or over electrically-sensitive parts of the muscles below the SCI. The specific type of electrical stimulation used with FES can trigger the nerve cells of movement (motor neurons) to send signals that cause muscle movement. An intact peripheral nerve and healthy muscle tissue is required to enable the external source of electricity to facilitate the muscle contraction.



FES does not work for nerve injuries outside the spinal cord

FES can only be used for muscle weakness or paralysis caused by injuries to the spinal cord, but not injuries to the conus medullaris, cauda equina, or the nerves outside of the spinal cord. The nerve cells in these structures (called *lower motor neurons*) must to be intact for FES to work.

Like exercise, regular sessions with FES are needed to maintain the effects of the treatment. For people with complete injuries, when FES treatments are stopped, the treatment effects will usually go away over time. For people with incomplete injuries, the goal is for some carryover of strength and movement be retained after the treatment is stopped.

Are there restrictions or precautions for FES?

There are some situations in which FES may be unsafe to use. This not a complete list, speak to a health provider about your health history and whether FES is safe for you.



FES should **not** be used in the following situations:

- Near implanted medical devices like heart pacemakers
- On areas of active cancer, or by people with bleeding disorders or other major medical conditions
- On areas with blood clots, bleeding, damaged skin, infection, or poor circulation
- By pregnant women

- Electrodes should not be placed over the eyes, through the head, through the chest or abdomen, or on the front of the neck or genitals
- By people with recent broken bones
- By people with damage to the nerves or muscles near the area where FES is used

FES should be used **with caution** in the following situations:

FES can sometimes be used with the following conditions when monitored closely. Speak to your health provider for more information.

- By people who have had seizures
- By people prone to **severe** autonomic dysreflexia (people with cervical and thoracic injuries)
- By people with uncontrolled spasticity
- By people with severe osteoporosis
- In areas where heterotopic ossification causes restricted movement
- In areas with reduced or absent sensation (below the level of injury)
- By people who are unable to follow instructions or provide accurate feedback

What are the risks and side effects of FES?

FES is generally well tolerated by people who can use it safely (see above for when FES may be unsafe). Serious medical complications from FES are rare. However, there are risks and side effects that should be discussed with a health provider before using FES.

More common risks and side effects of FES include:

- Discomfort or pain
- Skin redness or irritation
- Nausea, light-headedness, or autonomic dysreflexia

Other less common risks and side effects of FES include:

- Mild electrical burns near the electrodes
- Skin breakdown near the electrodes
- Fainting
- Worsening of muscle spasms (spasticity)
- Muscle and joint injuries, such as joint swelling or muscle strains
- Broken bones
- Mild electrical shocks (from improper use or faulty equipment)

In some cases, risks and side effects may be caused by improper use of the equipment. It is essential to learn to use the equipment from a health provider and to only use FES according to their direction and with the settings that they recommend.

For some people, side effects of FES may be stronger at first, but as their body gets used to FES with repeated treatments, their physical reactions may reduce over time.

Does FES improve strength and fitness after SCI?

Several studies have shown that FES helps to improve strength and fitness after SCI.

Strength



Studies have shown that both FES arm exercise and FES cycling helps to maintain or improve strength after SCI. However, FES cycling may be more effective for maintaining strength after injury than improving strength that has already been lost. This is supported by moderate evidence from five studies.

Cardiovascular fitness



Fifteen studies have looked at FES for improving many different aspects of fitness after SCI. Taken altogether, these studies provide weak evidence that FES training done at least 3 days per week for 2 months helps to improve many aspects of cardiovascular fitness after SCI.

Walking

Studies show that FES improves walking speed and distance in people with both incomplete and complete SCI. Some of these studies also showed that regular use of FES carried over to improve walking even without FES. This is supported by weak evidence from eight studies.



Does FES help with other complications of SCI?

The effects of FES treatment may also help to prevent complications of SCI like pressure sores, bone loss, spasticity, and orthostatic hypotension. These benefits may accompany gains in strength or fitness related to FES treatment.

Pressure sores



Although it is commonly thought that increased muscle bulk from FES will reduce the risk of pressure sores, there are not very many studies which have looked at whether this actually happens. One study provides weak evidence that FES cycling for 2 years reduced the number of pressure ulcers that occurred after SCI. Another study showed that regular FES cycling showed a trend towards reducing seat pressures.

Bone health

Research studies show that FES cycling does not *prevent* bone loss after SCI (moderate evidence from two studies). However, it may help to *increase* bone density that has already been lost, although the evidence for this is conflicting (based on six studies). It is not clear whether any gains in bone density last long-term or if continued FES treatment is needed for them to be maintained.



Spasticity

It is not clear what effects FES has on spasticity after SCI. There is conflicting evidence from three studies about whether FES cycling can help to reduce spasticity after SCI.

Orthostatic hypotension

Three studies provide moderate evidence that FES of the legs during a single change in position reduced orthostatic hypotension. However, this only shows that FES prevents orthostatic hypotension while it is applied, and further research is needed to look at what benefits this could have to people living with SCI.

The bottom line

Overall, the research evidence suggests that FES is most likely effective for improving muscle strength after SCI. It may also have effects on fitness, walking skills, bone density, skin health, spasticity, and orthostatic hypotension, although more high quality research is needed to confirm.

FES appears to be safe when used appropriately and is widely available in most rehabilitation settings. Discuss this treatment with your health providers to find out if it is a suitable treatment option for you.

For a list of included studies, please see the Reference List. For a review of what we mean by ‘strong’, ‘moderate’, and ‘weak’ evidence, please see [SCIRE Community Evidence Ratings](#).

Related resources

SCIRE Community. Body Weight Supported Treadmill Training. Available from:
<https://community.scireproject.com/topic/body-weight-supported-treadmill/>

SCIRE Community. Osteoporosis after Spinal Cord Injury. Available from:
<https://community.scireproject.com/topic/osteoporosis/>

SCIRE Community. Spasticity. Available from: <https://community.scireproject.com/topic/spasticity/>

Abbreviated Reference list

Parts of this page have been adapted from the SCIRE Project (Professional) “Lower Limb”, “Upper Limb”, “Bone Health”, “Cardiovascular Health and Exercise”, “Orthostatic Hypotension”, “Pressure Ulcers”, and “Spasticity” chapters:

Lam T, Wolfe DL, Domingo A, Eng JJ, Sproule S (2014). Lower Limb Rehabilitation Following Spinal Cord Injury. In: Eng JJ, Teasell RW, Miller WC, Wolfe DL, Townson AF, Hsieh JTC, Connolly SJ, Noonan VK, Loh E, McIntyre A, editors. *Spinal Cord Injury Rehabilitation Evidence. Version 5.0.* Vancouver: p 1-74.

Available from: <http://scireproject.com/evidence/rehabilitation-evidence/lower-limb/>

Connolly SJ, McIntyre A, Mehta, S, Foulon BL, Teasell RW. (2014). Upper Limb Rehabilitation Following Spinal Cord Injury. In Eng JJ, Teasell RW, Miller WC, Wolfe DL, Townson AF, Hsieh JTC, Connolly SJ, Noonan VK, Loh E, McIntyre A, editors. *Spinal Cord Injury Rehabilitation Evidence. Version 5.0:* p 1-77.

Available from: <http://scireproject.com/evidence/rehabilitation-evidence/upper-limb/>

Craven C, Lynch CL, Eng JJ (2014). Bone Health Following Spinal Cord Injury. In Eng JJ, Teasell RW, Miller WC, Wolfe DL, Townson AF, Hsieh JTC, Connolly SJ, Noonan VK, Loh E, McIntyre A, editors. *Spinal Cord Injury Rehabilitation Evidence. Version 5.0.* Vancouver: p 1- 37.

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Warburton DER, Krassioukov A, Sproule S, Eng JJ (2014). Cardiovascular Health and Exercise Following Spinal Cord Injury. In Eng JJ, Teasell RW, Miller WC, Wolfe DL, Townson AF, Hsieh JTC, Connolly SJ, Noonan VK, Loh E, McIntyre A, editors. *Spinal Cord Injury Rehabilitation Evidence. Version 5.0.* Vancouver: p. 1-48.

Available from: <https://scireproject.com/evidence/rehabilitation-evidence/cardiovascular-health-and-exercise/>

Krassioukov A, Wecht JM, Teasell RW, Eng JJ (2014). Orthostatic Hypotension Following Spinal Cord Injury. In: Eng JJ, Teasell RW, Miller WC, Wolfe DL, Townson AF, Hsieh JTC, Connolly SJ, Noonan VK, Loh E, McIntyre A, editors. *Spinal Cord Injury Rehabilitation Evidence. Version 5.0.* Vancouver: p. 1-26.

Available from: <https://scireproject.com/evidence/rehabilitation-evidence/orthostatic-hypotension/>

Hsieh J, McIntyre A, Wolfe D, Lala D, Titus L, Campbell K, Teasell R. (2014). Pressure Ulcers Following Spinal Cord Injury. In Eng JJ, Teasell RW, Miller WC, Wolfe DL, Townson AF, Hsieh JTC, Connolly SJ, Noonan VK, Loh E, McIntyre A, editors. *Spinal Cord Injury Rehabilitation Evidence. Version 5.0.* 1-90.

Available from: <https://scireproject.com/evidence/rehabilitation-evidence/pressure-ulcers/>

Hsieh JTC, Connolly SJ, McIntyre A, Townson AF, Short C, Mills P, Vu V, Benton B, Wolfe DL (2016). Spasticity Following Spinal Cord Injury. In Eng JJ, Teasell RW, Miller WC, Wolfe DL, Townson AF, Hsieh JTC, Connolly SJ, Curt A, Mehta S, Sakakibara BM, editors. *Spinal Cord Injury Rehabilitation Evidence. Version 6.0.*

Available from: <https://scireproject.com/evidence/rehabilitation-evidence/spasticity/>

Full reference list available from: <https://community.scireproject.com/topic/functional-electrical-stimulation/#reference-list>

Glossary terms available from: <https://community.scireproject.com/topics/glossary/>

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