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Using Electrical Stimulation

A Guideline for Allied Health Professionals

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Why use Electrical Stimulation?

Electrical stimulation (ES) is a means of producing contractions in muscles by applying an electrical current via electrodes placed on the skin, thereby stimulating nerves and muscle fibres¹. The nerves that send messages between the brain and the spine are called upper motor neurons (UMN), and those that relay messages from the spine to the muscle are called lower motor neurons (LMN). These neurons communicate via synapses in the anterior horn of the spinal cord. Damage to either an UMN or LMN may result in weakness (also known as muscle paresis) or paralysis. Generally, ES requires an intact LMN to effect a contraction in the stimulated muscle.

This document will primarily focus on the use of ES to augment motor control, either to help activate very weak muscle or to increase endurance.

There is evidence for the use of ES with a range of diagnosis including stroke², spinal cord injury^{3,4}, cerebral palsy⁵, and other neurological conditions⁶. There is strong evidence that ES is beneficial either as an adjunct to, or for strengthening muscles (maintenance of muscle bulk⁷), for functional retraining^{8,9} and gait retraining^{10,11}, as a substitute for muscle activity e.g. foot-drop neuroprotheses¹² or to help prevent shoulder subluxation^{13,14}. Additionally ES is thought to assist with maintaining joint range of motion following orthopaedic procedures, to reduce the effects of spasticity¹⁵, to increase local blood circulation, assist with wound healing, reduce pain¹⁶ and to improve sensory recovery¹⁷.

ES machines may work in the following ways:

- Single vs multi-channel
- Cyclic
- EMG triggered
- Pressure triggered
- Accelerometer-triggered
- Positional triggered
- Outcome-triggered
- Contralateral-triggered
- Neuroprosthesis

There are many several terms for ES which have slightly different meanings: Neuro-Muscular Electrical Stimulation (NMES) describes the application of surface electrodes over the desired muscle with the purpose of activating that muscle; Functional Electrical Stimulation (FES) describes the use of ES to assist with performance of a functional task such as taking a step or opening the hand to grasp an object; Transcutaneous Electrical Nerve Stimulation (TENS) is mainly used for pain management rather than muscle activation, and uses different stimulation parameters.

ES may also promote neuroplasticity¹⁸: the ability of the nervous system to change structurally and functionally as a result of behavioural input¹⁹. The brain and nervous system are able to change throughout life. Therefore therapists should use an active approach in rehabilitation that engage learners and is evidence-informed where possible. To maximise recovery, therapists should aim to provide interventions that:

1. Commence as early as possible
2. Are administered at the maximal intensity (frequency and number of repetitions) possible
3. Focus on client-centred goals
4. Are directed towards task-specific practice²⁰

Who is competent to use ES?

As with other interventions, ES can be prescribed and applied by qualified health professionals, including but not limited to physiotherapists and occupational therapists, who are competent in the use of ES, and

consider ES to be within their scope of practice. If training was not provided at university, allied health professionals can acquire competence by attending graduate workshops, or through workplace learning. The attached competency checklists identify the skills and knowledge that should be acquired before using ES. While students and allied health assistants can acquire competence in the use of ES, these groups would not usually prescribe ES parameters.

What information should be provided to patients?

All patients should provide verbal consent to ES prior to its use

Therapists should ensure that patients or users, and their carers have the necessary information to make an informed decision and consent to the use of ES before it is used. This information should include:

- What skin sensation they might expect to feel during the treatment
- What sensation they should not feel and responses that are unwanted
- What to do if they experience unwanted responses
- How to adjust the controls and turn the machine off (if patient or carer is able)

A family member or carer should be present if possible to jointly receive this information. A written handout, in lay terminology with illustrations may also be provided.

The ES information provided to patients and carers should be documented. Information documented in medical records may include:

1. Medical contraindications and cautious considered
2. Informed consent provided
3. Treatment details, which could include machine used, waveform parameters (frequency, pulse width), intensity, duty cycle or on: off ratio, response (sensory, motor, pain), duration of treatment, location and types of electrodes
4. Immediate result of treatment including any abnormal reactions and subsequent action taken or recommendation made for future treatment

What are the Safety Considerations for ES?

Reasons for NOT using ES include the following contraindications

- ES in the vicinity of the uterus while pregnant
- ES over inbuilt stimulator (e.g. pacemaker) unless the risk has been evaluated by a relevant medical specialist²¹

Reasons for being cautious about prescribing ES include:

- Circulatory insufficiencies
- Risk of dissemination, e.g. acute infections, tumours, TB, osteomyelitis, severe organ states such as cardiac failure
- Communication impairments: Inability to effectively communicate and in turn, to make informed decisions etc
- Visible skin or cell injury: Avoid application over broken skin or haematoma
- People with high level spinal cord injury: Damage above T6 may cause patients to experience episodes of autonomic dysreflexia when ES is used.

How to use an ES Machine

To set-up

1. Decide on the functional goal for use of ES and the relevant muscle(s) to stimulate.
2. Test the device on yourself to make sure that it is functioning correctly.
3. Locate appropriate proximal and distal electrode placement on skin surface of muscle.
4. Clean skin with soap and water.
5. Select size/shape of electrode appropriate to target muscle belly.

6. Apply electrodes (either self-adhesive or carbon rubber electrodes with gel or wet pad to facilitate conduction of the current) and ensure that electrodes are at least 1cm apart and attached firmly (Manufacturers may recommend that one electrode be placed more proximally however this appears to make little difference to the outcome of ES). If using pre-gelled (adhesive) electrodes – these should only be used with a single patient and then discarded. Carbon rubber electrodes can be used with multiple patients if sterilised between each use.
7. Increase the current intensity slowly until the desired response is observed. Set repetition timing appropriate for the treatment goal (unless using a triggering device).
8. Monitor the patient: check skin integrity (i.e. in patients with reduced sensation check more regularly for heat and redness) and patient comfort.
9. Provide patients and their carers with written information about ES, including how to operate the device and how it will be used as part of their therapy program (e.g. use of EMG or other forms of current triggering, as well as any concurrent exercises).

Problem-solving and/or trouble shooting

Factors to consider if the desired outcome (a muscle contraction) is not achieved:

- Battery power (may need to be replaced)
- Electrode integrity (electrodes may be conducting poorly or placed too close together)
- Cable integrity
- Skin integrity (clean skin again/advice patient not to moisturise prior to ES)
- Hair (trim hair close rather than shaving)
- Skin lotions (these increase skin impedance and electrodes will not stick if skin is greasy)
- Adipose tissue (may impede signal)
- Muscle response may not be seen immediately in some people with chronic paresis. Several attempts may be needed, including multiple repositioning of electrodes, before a visible muscle contraction is achieved.

How should ES be prescribed and applied to optimise outcomes?

Frequency (Hz): Frequency refers to the number of electrical pulses per second. Typically, a frequency between 30 and 50 Hz will be used, but up to 100Hz is not uncommon in neuro-rehabilitation. Different frequencies achieve different muscle responses, as follows:

- Lower than about 30 Hz: The patient should feel individual muscle twitches or a tremor.
- Between 30 – 50 Hz: The tremor turns into a continuous muscle contraction known as tetany, needed for limb movement.
- Up to 100Hz: Muscle contractions will increase in strength proportionally with frequency. At the point of contraction, little additional effect is noted with increased frequency. The lowest frequency that achieves a 'smooth' tetanic contraction should be used.
- Between 20 – 100 Hz: Type I fibres tend to be activated at around 20 – 35 Hz, type IIa fibres between 30 – 50 Hz and type IIb fibres between 45 – 70 Hz.

Patients may find that higher frequencies cause unacceptable discomfort. Although force of contraction increases with higher frequencies, faster twitch muscle fibres are recruited, which can fatigue more quickly. Thus higher frequencies may not be helpful when stimulating very weak muscles, or when trying to increase endurance (reducing muscle fatigability).

Pulse duration (μ s): Pulse width or duration refers to the time span that a single electrical pulse or current is flowing actively. Typically, a pulse width between 200 and 250 μ s is used in neuro-rehabilitation. Most ES machines have a range of 50 – 450 μ s. A pulse duration of 250 μ s will provide current for 250 millionths of a second. After depolarisation of a nerve's membrane potential there must be a period of repolarisation (called the refractory period) where no stimulus will cause another impulse.

Short duration pulses tend to be more comfortable but longer duration pulses proportionally increase the amount of electrical power being supplied to assist muscle contraction. The longest pulse durations, around 350 – 450 μs , can be used to cause paretic fibres to contract. As pulse duration is increased there is less difference between the pulse amplitudes at which sensory, motor and pain nerve fibres are stimulated. Therefore at 450 μs pain may occur simultaneously with motor stimulation, whereas at 50 μs motor stimulation may begin at much lower pulse amplitude than pain.

Ramp up and down(s): Ramping or gradually changing the rate at which the current achieves maximal amplitude helps mimic how muscles are normally recruited for function, and will be more comfortable for users. Most ES machines have an available range of ramp times between 0.3 and 9.9 seconds; however some only allow the ramp to be adjusted at the beginning of the 'on' cycle and will automatically derive the rate at which the current decreases at the end of the cycle. Ramping up the current gradually rather than applying full power instantaneously allows gradual excitation of nerve fibres. An example of the use of 'ramp up' for ES would be stimulation of wrist extension for upper limb training, allowing time for the patient to try activating the extensor muscles themselves and 'assist' the movement of extending the wrist and fingers. Ramp down could be used to assist an eccentric contraction of the dorsiflexors in controlling 'foot slap' or to allow the gradual descent (assisted by gravity) of the unsupported humerus when treating shoulder subluxation. When using ES for gait training, very short or no 'ramp up' is useful as the dorsiflexor muscles need to activate very quickly during the swing phase of gait for foot clearance to occur.

Synchronous vs. Alternating Channels: Multi channel ES devices (which typically have two channels or ports, for two sets of electrodes) can be programmed to deliver either synchronous or alternating (reciprocal) pulses. If the device is set for 'synchronous' then the two channels will administer stimulation simultaneously causing two muscle groups to contract at the same time, (e.g. thumb abduction with wrist extension). If the device is set to 'alternating' the two channels will deliver stimulation reciprocally (e.g. stimulation of dorsiflexors followed by plantarflexors during the gait cycle, or wrist extension followed by wrist flexion, to help reduce hand oedema). Alternating sequences are only possible within cyclic programs. Within all other applications dual channel machines must be synchronous.

Duty cycle (s): Duty cycle refers to the duration of the on/off period of stimulation. The duty cycle aims to mimic the functional movement being re-trained but also take into consideration muscle endurance. For example although gleno-humeral stability in non-impaired people is achieved by very long duration muscle activity, someone with a neurological impairment might have very weak muscles which fatigue quickly. Stimulation time can be increased as endurance improves. ES protocols to prevent gleno-humeral subluxation in people with limited control around the shoulder gradually increase the ON time, and reduce the OFF time, for example, until a ratio of 30 seconds ON to 3-5 seconds OFF is achieved. With most other training protocols, the OFF time will be around 3 times longer than the ON time, to allow muscles to recover.

Threshold (μV or mV): ONLY RELEVANT IN EMG TRIGGERED STIMULATION. When using electromyography (EMG) triggered ES, an EMG threshold is set as a target for the person to achieve in order to trigger electrical stimulation. As the person's muscle contraction becomes stronger, the threshold can be increased. Some EMG triggered ES machines have an automated threshold for EMG activity. As an example the threshold for someone trying to activate the triceps might initially be 10 μV but as the patient becomes stronger the threshold might be increased to 50 μV - requiring the patient to work harder. Some machines have an automatic adjustment function for this purpose. In order to use EMG triggered stimulation the user must have sufficient muscle activity to be detected by the machine. The EMG threshold can be set on most machines to a level that will detect minimal muscle activation.

Intensity / Amplitude (mA): Intensity refers to the current. Intensity may be varied between 0 and 140mA on some machines. Intensity must be high enough to create a muscle contraction but a maximal contraction

is not required in most ES applications. Because ES activates only a pool of motor units underneath the surface electrodes, there is a point at which increasing the intensity will not produce a greater contraction, but will increase the level of discomfort experienced. Intensity required to achieve the desired contraction will vary from one patient to another depending on individual sensation, skin resistance (impedance), size of muscle and the type and size of electrodes. Intensity may also vary from one session to another depending on the integrity of the electrodes and their contact with the skin, and also skin impedance (for instance how well any surface oils have been removed). Additionally intensity may need to be increased during the session to adjust for accommodation.

Session duration (mins): In order to consider the effects of muscle fatigue it may be beneficial to begin with shorter sessions and gradually increase the treatment time.

Table 1. Examples of a schedule of ES for a new user with a neurological condition (eg stroke)

5-10 mins	Trial of stimulation Muscle activation exercise in early retraining of movement
10-30 mins	Early session when fatigue may be observed and skin sensitivity is unknown
30-45 mins	Approximate recommendation for functional practice
45-100 mins	Approximate recommendation for sustained contractions (e.g. shoulder subluxation protocols)

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Appendices

**COMPETENCY CHECKLIST FOR THERAPISTS
ASSESSMENT, APPLICATION AND REMOVAL OF ELECTRICAL STIMULATION (ES)**

PT/OT		Signature	
Reviewer		Signature	
Date of review			
✓ : performed adequately		X: not performed adequately	✓/x
Preparation (prior to client contact)			Comments
<ol style="list-style-type: none"> 1. Read designated articles and relevant ES guidelines 2. Review appropriate anatomy 3. Attend training with senior therapist on assessment, application of ES and post-procedure 			
Assessment and intervention planning			
<ol style="list-style-type: none"> 4. Identify appropriate clients to receive ES 5. Identify contraindications and precautions for using ES 6. Follow procedure to book out ES machine 7. Identify client's activity limitation(s) 8. identify functional, client-centred goal(s) 9. Gain consent, plan intervention protocol, ES parameters, timetable and re-assessment 			
Performance of task			
<ol style="list-style-type: none"> 10. Provide information to client on the purpose of ES, how machine works, intervention plan and when to seek advice 11. Client preparation: <ol style="list-style-type: none"> a. Position client appropriately b. Clean skin with soap and water 12. Device preparation: <ol style="list-style-type: none"> a. Set appropriate stimulation parameters b. Position electrodes correctly to achieve desired outcome c. Ensure electrodes are secure (use gel with rubber electrodes, sufficiently stuck down with sticky electrodes) d. Check leads are plugged fully into correct sockets 13. Switch on device and select appropriate intensity. Reposition electrodes if needed and modify parameters until desired contraction is observed. 14. Advise client/carer how to switch device on/off and store electrodes. 15. Monitor first session closely (skin reactions, pain, sensation, correct movement elicited, fatigue) 16. Plan progression of intervention according to reassessment findings and compliance 17. Encourage client to be an active participant in the session (where appropriate) 18. Arrange loan of equipment for ward/home use 			
Post procedure			
<ol style="list-style-type: none"> 19. Check skin response 20. Document details of session and any adverse effects in medical file 			

**COMPETENCY CHECKLIST FOR
THERAPY ASSISTANTS, STUDENTS AND NURSING STAFF
APPLICATION AND REMOVAL OF ELECTRICAL STIMULATION (ES)**

Therapy Assistant / Nurse		Signature	
Reviewer		Signature	
Date of review			
✓: performed adequately		X: not performed adequately	✓/X
Preparation (prior to client contact)			Comments
<ol style="list-style-type: none"> 1. Read designated articles and relevant ES guidelines 2. Review handout on ES for families/clients 			
Performance of task			
<ol style="list-style-type: none"> 3. Have good understanding about the purpose of ES and how it works to be able to deal with questions from client/families/carers/others appropriately 4. Client preparation: <ol style="list-style-type: none"> a. Position client appropriately b. Clean skin with soap and water 5. Device preparation: <ol style="list-style-type: none"> a. Set appropriate stimulation parameters b. Position electrodes correctly to achieve desired outcome c. Ensure electrodes are secure (use gel with rubber electrodes, sufficiently stuck down with sticky electrodes) d. Check leads are plugged fully into correct sockets 6. Switch on device and select appropriate intensity. Reposition electrodes if needed and modify parameters until desired contraction is observed. 7. Advise client/carer how to switch device on/off and store electrodes. 8. Have clear understanding of intended muscle activation of ES and appropriate trouble shooting pathways if muscle activation is unsuccessful 9. Inform client of duration of ES 10. Advise client to alert staff member if any concerns 11. Educate client/carer/nursing staff on how to store machine and electrodes 			
Post procedure			
<ol style="list-style-type: none"> 12. Check skin response 13. Document details of session and any adverse effects in medical file 			

**PATIENT/CARER TRAINING CHECKLIST FOR
SELF TREATMENT
APPLICATION AND REMOVAL OF ELECTRICAL STIMULATION (ES)**

Client (Carer)		Signature	
Therapist		Signature	
Date of review			
✓: performed adequately X: not performed adequately- further training or practice needed.		✓/X	Comments
Preparation			
1. Has knowledge of how the ES machine operates			
Performance of task			
2. Client preparation:			
a. Position client appropriately			
b. Clean skin with soap and water			
3. Device preparation:			
a. Set appropriate stimulation parameters			
b. Position electrodes correctly to achieve desired outcome			
c. Ensure electrodes are secure (use gel with rubber electrodes, sufficiently stuck down with sticky electrodes)			
d. Check leads are plugged fully into correct sockets			
4. Switch on device and select appropriate intensity. Reposition electrodes if needed and modify parameters until desired contraction is observed.			
5. Have clear understanding of intended muscle activation of ES and appropriate trouble shooting pathways if muscle activation unsuccessful			
6. Switch off machine at appropriate time			
7. Store machine and electrodes appropriately			
Post procedure			
8. Check skin response			
9. Document in treatment diary			