# Transcutaneous electrical nerve stimulation (TENS) for phantom pain and stump pain following amputation in adults (Review)

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[Intervention Review]

# Transcutaneous electrical nerve stimulation (TENS) for phantom pain and stump pain following amputation in adults

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## ABSTRACT

### Background

Amputee pain may present in a body part that has been amputated (phantom pain) or at the site of amputation (stump pain), or both. Phantom pain and stump pain are complex and multidimensional and the underlying pathophysiology remains unclear. The mainstay treatments for phantom pain and stump pain are predominately pharmacological. The condition remains a severe burden for those who are affected by it. There is increasing acknowledgement of the need for non-drug interventions and Transcutaneous Electrical Nerve Stimulation (TENS) may have an important role to play. TENS has been recommended as a treatment option for phantom pain and stump pain. To date there has been no systematic review of available evidence and the effectiveness of TENS for phantom pain and stump pain is currently unknown.

### Objectives

To assess the analgesic effectiveness of TENS for the treatment of phantom pain and stump pain following amputation in adults.

### Search methods

We searched MEDLINE, Cochrane Central Register of Controlled Trials (CENTRAL), EMBASE, PsycINFO, AMED, CINAHL, PEDRO and SPORTDiscus (February 2010).

### Selection criteria

Only randomised controlled trials (RCTs) investigating the use of TENS for the management of phantom pain and stump pain following an amputation in adults were included.

### Data collection and analysis

Two review authors independently assessed trial quality and extracted data. It was planned that where available and appropriate, data from outcome measures were to be pooled and presented as an overall estimate of the effectiveness of TENS.

### Main results

No RCTs that examined the effectiveness of TENS for the treatment of phantom pain and stump pain in adults were identified by the searches.

**Authors' conclusions**

There were no RCTs on which to judge the effectiveness of TENS for the management of phantom pain and stump pain. The published literature on TENS for phantom pain and stump pain lacks the methodological rigour and robust reporting needed to confidently assess its effectiveness. Further RCT evidence is required before such a judgement can be made.

## PLAIN LANGUAGE SUMMARY

**Transcutaneous electrical nerve stimulation (TENS) for phantom pain and stump pain following amputation in adults**

Amputee pain may present in a body part that has been amputated (phantom pain) or at the site of amputation (stump pain), or both. Phantom pain and stump pain are complex conditions and affect up to 80% of amputees. The underlying causes are not fully understood. Drug therapy is the most common treatment yet the condition remains poorly managed. The need for non-drug interventions has been recognised and TENS may have an important role to play. TENS is an inexpensive, safe and easy to use analgesic technique which consists of a battery powered, portable device which generates electrical currents that are passed across the intact surface of the skin to activate underlying nerves. A search of various databases found no studies that met the eligibility criteria for inclusion in this review which prevents any judgement on the effectiveness of TENS for phantom pain and stump pain. A large multicenter randomised controlled trial is needed.

## BACKGROUND

Up to 80% of amputee patients report pain following amputation that affects quality of life and hinders rehabilitation, including the use of prosthetic limbs (Ephraim 2005; Nikolajsen 2001).

Amputee pain may present in a body part that has been amputated (phantom pain) or at the site of amputation (stump pain), or both (Wilson 2008). Non-painful sensations may also present in a phantom body part or a stump, or both (Nikolajsen 2001). Often patients present with a unique combination of symptoms (Nikolajsen 2001; Wiffen 2006). The underlying pathophysiology is unclear, however, it is generally accepted that nociceptive and neuropathic processes are involved and that neuropathic changes include reorganisation and adaptation within the peripheral and central nervous systems (Flor 2002).

Multimodal treatment strategies are used including analgesics, muscle relaxants, vasodilators, sympathetic blocks, sympathectomies, surgical revision of the stump, stimulation-induced analgesic techniques and mirror box therapy (Flor 2002; Hanling 2010, Sherman 1994; Sindrup 1999). Despite a multitude of treatments, a study of 92 amputees revealed that only 9% were pain free (Smith 1999). In 2002 a systematic review of available treatment regimes concluded that it was not possible to determine optimal treatments for the management of phantom limb pain based on available evidence (Halbert 2002).

Transcutaneous Electrical Nerve Stimulation (TENS) is an inexpensive, safe and easy to use analgesic technique. A 'standard TENS device' consists of a battery powered, portable device which generates electrical currents which are passed across the intact surface of the skin, via surface/skin electrodes, to activate underlying nerves (Johnson 2008). Users can adjust the pulse amplitude, pulse frequency, pulse duration and pulse pattern of the currents. TENS can be used to stimulate large diameter A-beta afferents to elicit segmental analgesia (conventional TENS) or to stimulate smaller diameter A-delta afferents to elicit extrasegmental analgesia (Acupuncture-like TENS) (Charlton 2005; Johnson 2007a). TENS is used as a stand-alone treatment and in combination with other treatments for a wide variety of acute and chronic pains, including phantom pain and stump pain (Johnson 2007a; Walsh 1997).

Physiological research suggests that TENS inhibits second order nociceptive neurons (Garrison 1994; Garrison 1996), increases blood flow (Chen 2007; Cramp 2001), and reduces muscle spasms (Avdic 2000). It is plausible that these actions could alleviate phantom pain, stump pain, or both.

Systematic reviews of TENS for acute pain have reported positive outcomes for primary dysmenorrhoea (Proctor 2002), conflicting outcomes for postoperative pain (Bjordal 2003; Carroll 1996) and inconclusive outcomes for labour pain (Dowswell 2009). A recent Cochrane Review of TENS for acute pain (Walsh 2009) concluded that there is insufficient evidence to make any definitive conclusions about the effectiveness of TENS for acute pain in

adults. Systematic reviews of TENS for chronic pain have reported positive outcomes for chronic recurrent headache (Bronfort 2004) and musculoskeletal pain (Johnson 2007b), and inconclusive outcomes for low back pain (Khadilkar 2008), knee osteoarthritis (Rutjes 2009; Bjordal 2007), rheumatoid arthritis of the hand (Brosseau 2003), post-stroke shoulder pain (Price 2000), cancer-related pain (Robb 2008) and whiplash and mechanical neck disorders (Kroeling 2009). A recent Cochrane Reiview of TENS for chronic pain (Nnoaham 2008) concluded that the lack of methodological rigour and robust reporting of published literature prevents the confident assessments of the role of TENS in chronic pain management. Many reviews are inconclusive, although, more positive outcomes are reported when adequate TENS techniques are taken into account (Bjordal 2003; Bjordal 2007). Bjordal 2003 suggested adequate TENS technique to be >15mA (above sensory threshold, but sub noxious), at a frequency of between 25-150Hz and electrodes applied to produce paraesthesia at the site of pain.

Nevertheless, TENS has been recommended as a treatment option for phantom pain and stump pain (Black 2009; Jensen 2006). Published case series and controlled clinical trials suggest that TENS may be of benefit (Carabelli 1985; Finsen 1988; Gyory 1977; Katz 1989; Katz 1991; Kawamura 1997; Thorsteinsson 1977; Wartan 1997). To date, there has been no systematic review of available evidence to judge the effectiveness of TENS for phantom pain and stump pain.

# OBJECTIVES

To systematically review the analgesic effectiveness of TENS for the treatment of phantom pain and stump pain following amputation in adults.

# METHODS

## Criteria for considering studies for this review

### Types of studies

All randomised controlled trials (RCTs) (crossover and parallel group design) investigating the use of TENS for the management of pain following amputation were sought. The following types of studies were excluded: trials that were not randomised; trials of experimental pain; case reports; clinical observations; and, letters, abstracts and reviews (unless they provided additional information from published RCTs that met the criteria).

### Types of participants

Adult participants (16 years or above) with any limb amputation resulting in pain, in a phantom limb or the stump, or both, which can be described as any of: sharp, dull, burning, squeezing, cramping, shooting or a shock-like electrical sensations. Participants whose amputation had occurred for any reason were eligible for inclusion in this review.

### Types of interventions

Only studies that evaluated surface electrical nerve stimulation for the management of phantom pain or stump pain, or both, following amputation were included (i.e. transcutaneous as opposed to percutaneous electrical stimulation). Studies were included only if they:

1. used a TENS device which delivered biphasic or monophasic pulsed electrical currents in the mA range. This included delivery of currents using the following devices: standard TENS device, Neuromuscular Electrical Stimulation devices (NMES), Functional Electrical Stimulation (FES), Interferential Current devices (IFC) and single electrode probes (i.e. TENS pens);
2. administered TENS at pulse amplitudes that produced 'strong and comfortable' paraesthesia that was felt by the participant (i.e. conventional TENS or acupuncture-Like TENS, or both). TENS delivered at intensities reported to be 'barely perceptible', 'faint' or 'mild' were excluded;
3. administered TENS in an area of the body that was sensate either at i) the site of pain, ii) over nerve bundles proximal to the site of pain, iii) on the contralateral limb at the mirror site to the phantom limb pain, iv) known acupuncture points;
4. used any parameters of stimulation providing they met the above criteria.

The planned intervention comparisons were the following.

- TENS versus no treatment controls.
- TENS versus sham controls. Sham controls are defined as any electrotherapeutic device that has been modified so that there is no active output (i.e. dummy device).
- TENS versus a pharmacological intervention.
- TENS versus a non-pharmacological intervention.

It was intended that studies would be excluded from the analysis if TENS was administered in combination within another intervention as part of the formal study design; for example additional analgesics or exercise. It was intended that studies where participants continued with their usual medications would be included as well as studies where participants were given rescue medication because the potential impact on pain scores was thought to be minimal.

### Types of outcome measures

### Primary outcomes

Patient reported pain using standard subjective validated scales (e.g. Visual Analogue Scales (VAS) or Numerical Rating Scale (NRS)).

### Secondary outcomes

- any other related pain measure designed to capture data pertaining to the characteristics and quality of pain (e.g.: McGill Pain Questionnaire)
- patient reported non-painful phantom sensations using validated scales
- patient satisfaction
- activities of daily living and ambulation
- range of movement*
- Quality of Life
- anxiety/depression
- use of pain coping strategies
- sleep**
- analgesic consumption
- hospital attendance
- other healthcare interventions e.g. physiotherapy visits, hospice admissions, day care etc
- any adverse effects.

* range of movement may not measure the actual range of movement possible but the range of movement that is comfortable;
** if 'sleep' outcomes are reported these may be heterogeneous and subcategories were planned in the analysis rather than combining all sleep outcomes together - no sleep studies were identified so this was not an issue.

## Search methods for identification of studies

**The following data sources were searched in February 2010.**

1. MEDLINE 1950 to February 2010.
2. Cochrane Central Register of Controlled Trials (CENTRAL) 1800 to February 2010.
3. EMBASE 1980 to February 2010.
4. PsycINFO 1806 to February 2010.
5. AMED 1985 to February 2010.
6. CINAHL 1982 to February 2010.
7. PEDRO 1929 to February 2010.
8. SPORTDiscus 1975 to February 2010.

To identify studies for inclusion in the review, detailed search strategies were developed for each electronic database searched. These were based on the search strategy developed for MEDLINE and were revised accordingly for each database. See Appendix 1 for the MEDLINE search strategy and Appendicies 2 - 8 for the subsequent search strategies. For the MEDLINE search, the subject search was run with the following filter: Cochrane Highly Sensitive Search Strategy (CHSSS) for identifying randomised trials in MEDLINE (via OVID): sensitivity maximising version (2008 revision) as referenced in Chapter 6.4.11.1 and detailed in box 6.4.a of The Cochrane Handbook for Systematic Reviews of Interventions Version 5.0.0 (Higgins 2008).
Reference lists of all eligible trials, key textbooks and previous systematic reviews were searched for additional studies.

### Language

The search strategy attempted to identify all relevant studies irrespective of language. Non-English papers were assessed and translated if necessary.

## Data collection and analysis

### Selection of studies

From the titles, abstracts and descriptors, two independent review authors (MM and MJ) reviewed the results of the literature searches to identify potentially relevant studies for the full review. Disagreements were resolved through discussion with a third review author (A-MB). Review authors were not blinded to the authors' names and institutions, journal of publication, or study results at this or any stage of the review.

### Data extraction and management

It was intended that for each included study, data would be extracted on: authors, participants, trial design, characteristics of interventions (TENS settings, application, treatment schedules, concurrent interventions), adverse effects and baseline and end of study outcomes. It was intended that three review authors would complete data extraction (MM, MJ, A-MB) independently. Disagreements were to be resolved by consensus. Where necessary, additional information was sought from study authors of relevant trials.

### Assessment of risk of bias in included studies

It was intended that the risk of bias of any included studies would be assessed independently by the review authors MM, MJ, A-MB and PM, using The Cochrane Collaboration's tool for assessing risk of bias in RCTs (Higgins 2008).

### Measures of treatment effect

It was planned that where available and appropriate, data from outcome measures were to be pooled and presented as an overall estimate of the effectiveness of TENS. It was intended that

the appropriateness of pooling would first have been assessed on the basis of clinical heterogeneity in terms of participants, settings, interventions and comparisons, dose intensity, outcomes measured and timing of outcome measurements; and on the basis of methodological heterogeneity. For each study, relative risk (RR) with 95% confidence intervals (CI) would have been calculated for dichotomous outcomes. For continuous outcomes reported using the same scale, pooled results would have been presented as mean difference (MD). Standardised mean differences (SMD) would have been calculated where results for the same continuous outcome had been measured using different scales. The number needed to treat to benefit (NNT) for treatment effect would have been calculated where appropriate.

### Unit of analysis issues

It was intended that if categorical data could not be split into dichotomous outcomes, it would not be included in a meta-analysis but was to be reported in tables and in the text.

In the case of crossover trial designs, it was anticipated that the data reported would not permit analysis of paired within-patient data. Crossover trials were thus intended to be analysed as if they were parallel group trials, combining data from all treatment periods. If a carry-over effect was found and data were reported by period, then the analysis was to be restricted to period-one data only. In those rare cases in which complete data are reported, within-patient improvement scores were to be calculated.

It was intended that if combining studies in a meta-analysis was not possible, a narrative description of included studies would be provided.

### Dealing with missing data

It was intended that if studies reported outcomes that could not be included in the meta-analysis, either for reasons already mentioned, or because there was missing summary data (e.g. absent standard deviations) or the report showed that the data evidently came from a skewed distribution, the study findings were to be reported in tables and in the text under the appropriate headings.

### Assessment of heterogeneity

It was planned that estimates of effectiveness (both SMD and RR) were to be tested for statistical homogeneity, by visual inspection of the forest plot and by using the Chi-Squared test and $I^2$ test of heterogeneity. Substantial statistical heterogeneity were to be judged to be present where the P value for the Chi-square test < 0.01 or the value for $I^2$ was 50% or above. If effect estimates were consistent with homogeneity, they were to be combined using a fixed-effect model. If statistical heterogeneity was present, an attempt would have been made to explain the differences based on the clinical and methodological characteristics of the included studies, and studies thought to be the cause of statistical heterogeneity would have been excluded from the analysis. Clinically dissimilar studies would not have been statistically combined. However, if a group of studies with heterogeneous results appeared to be clinically similar, the study estimates would have been combined using a random-effects model and the results interpreted with caution.

### Subgroup analysis and investigation of heterogeneity

Where the data allowed, it was planned to separate the outcome analyses to test the following null hypotheses.

1. There is no difference in patient reported amputee pain for different causes of amputation.
2. There is no difference in patient reported amputee pain for different levels of amputation.
3. There is no difference in patient reported amputee pain for different TENS application technique.

### Sensitivity analysis

It was planned that a sensitivity analysis would be performed when indicated to investigate the effects of allocation concealment, overall methodological quality and use of intention-to-treat (ITT) analysis. It was intended that trials with high attrition rates (i.e. more than 50%) would have been removed from the meta-analysis to see if the results were significantly different without them.

## RESULTS

### Description of studies

See: Characteristics of excluded studies.

In total 72 published articles were identified by the searches. Fourteen studies were considered to be relevant to the aims of this review, but none met the eligibility criteria for a RCT (see 'Characteristics of excluded studies'). The fourteen potentially relevant articles were classified as follows: four case reports (Giuffrida 2009; Gyory 1977; Hirano 1988; Katz 1989); eight case series (Carabelli 1985; Heidenreich 1988; Kawamura 1997; Miles 1978; Salim 1997; Sindou 1980; Stolke 1978; Winnem 1982); and two placebo controlled non-randomised trials (Finsen 1988; Katz 1991). Finsen 1988 claimed to have randomised patients to one of three treatment regimes. However, they authors report that after 18 months there was unequal distribution of amputation levels between the three groups and recruitment and randomisation was "improved by taking into account the amputation level". It was felt that the adjustment of recruitment and randomisation procedures compromised randomisation and the possibility of purposive sampling cannot be discounted.

### Risk of bias in included studies

There were no included studies, so bias could not be evaluated.

### Effects of interventions

There were no included studies, so effects could not be evaluated.

## DISCUSSION

No RCTs examining the effectiveness of TENS for the treatment of phantom pain and stump pain in adults were identified by the searches. Thus, no judgement of effectiveness can be made due to the lack of methodological rigour in available studies. This problem was identified in a systematic review by Halbert 2002 and no RCTs have been published since.

Ten of the excluded studies reported benefit from using TENS (Carabelli 1985, Hirano 1988, Giuffrida 2009, Gyory 1977, Katz 1989, Kawamura 1997, Miles 1978, Salim 1997, Sindou 1980, Winnem 1982), one reported no benefit effects from using TENS (Finsen 1988), two were inconclusive (Katz 1991, Heidenreich 1988) and one did not provide sufficient information for a verdict to be made (Stolke 1978). Two of these studies included a sham TENS group but neither implement adequate randomisation procedures and both failed to report methods of sequence generation (Finsen 1988, Katz 1991). Finsen 1988 found that low frequency (2Hz) segmental TENS reduced healing times and re-amputation rates when compared to sham TENS but found there was no difference in analgesic consumption between the groups. No direct measure of pain was made. Katz 1991 reported "modest reduction" in phantom limb pain after ten minutes of auricular TENS application relative to pre-TENS baseline pain scores, however no analysis was reported for active versus sham TENS. Hence, it was not possible to determine whether there was a statistical difference between active and sham TENS for pain outcome in both these studies.

Other shortcomings of the excluded studies were omission of a sample size calculation, failure to report blinding procedures and whether blinding was maintained, and insufficient details on TENS technique, including whether TENS was applied at a sufficiently strong intensity.

Nevertheless, the positive trend towards pain relief in some of the excluded studies suggests that TENS may be beneficial for some individuals and that a large multicenter RCT, which accounts for previous shortcomings, is needed.

## AUTHORS' CONCLUSIONS

### Implications for practice

There is insufficient evidence from RCTs to judge whether TENS should, or should not, be used in the management of phantom pain and stump pain in adults.

### Implications for research

Further evidence is required before any judgements on effectiveness can be made. A large multicenter adequately powered RCT with appropriate procedures for sequence generation, allocation concealment and blinding is needed. Data provided in the reports of the excluded studies may prove useful in calculating sample size. Future studies need to ensure that TENS is delivered at a strong non painful intensity within or close to the site of pain (Bjordal 2003) using appropriate technique in line with best practice (Johnson 2008). Pain outcomes should be measured whilst the TENS device is switched on, rather than before and after TENS, and the duration and frequency of each treatment recorded when TENS is used at home. Means and standard deviations for continuous data should be reported as standard to enable data extraction for subsequent meta-analysis.

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Walsh DM, Howe TE, Johnson MI, Sluka KA. Transcutaneous electrical nerve stimulation for acute pain. *Cochrane Database of Systematic Reviews* 2009, Issue 2. [DOI: 10.1002/14651858.CD006142.pub2]

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Wartan SW, Hamann W, Wedley JR, McColl I. Phantom pain and sensation among British veteran amputees. *British Journal of Anaesthesiology* 1997;**78**(6):652–9.

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Wiffen P, Meynadier J, Dubois M, Thurel C, deSmet J, Harden RN. Diagnostic and treatment issues in postamputation pain after landmine injury. *Pain Medicine* 2006;**7 Suppl 2**:209–12.

**Wilson 2008**
Wilson JA, Nimmo AF, Fleetwood-Walker SM, Colvin LA. A randomised double blind trial of the effect of pre-emptive epidural ketamine on persistent pain after lower limb amputation. *Pain* 2008;**135**(1-2):108–18.

* *Indicates the major publication for the study*

## CHARACTERISTICS OF STUDIES

### Characteristics of excluded studies *[ordered by study ID]*

| Study | Reason for exclusion |
|---|---|
| Carabelli 1985 | Case series. |
| Finsen 1988 | Pain assessment was not primary outcome. TENS was used with the intention of increasing peripheral vasodilation in order to decrease stump wound healing time and decrease re-amputation rates. Randomisation was compromised by taking into account level of amputation prior to randomisation |
| Giuffrida 2009 | Report of two cases of contralateral TENS for phantom limb pain |
| Gyory 1977 | Case report of prosthetic socket TENS. |
| Heidenreich 1988 | Case series of conservative management of phantom limb pain. |
| Hirano 1988 | Case report. |
| Katz 1989 | Case report of contralateral TENS & stump skin conductance. |
| Katz 1991 | Non-randomised controlled trial of auricular TENS for phantom sensations and phantom pain |
| Kawamura 1997 | Case series of contralateral TENS for phantom limb pain. |
| Miles 1978 | Case series electrical stimulation for phantom limb pain. |
| Salim 1997 | Case series of TENS for phantom limb pain. |
| Sindou 1980 | Case series of TENS for neuropathic pain. |
| Stolke 1978 | Case series of electrostimulation of stump & phantom limb pain |
| Winnem 1982 | Case series of TENS for phantom limb pain. |

## DATA AND ANALYSES

This review has no analyses.

## APPENDICES

### Appendix 1. MEDLINE search strategy

**MEDLINE via Ovid search (1950 - February 2010)**

[mp=title, original title, abstract, name of substance word, subject heading word]
1. (tens or al-tens or tns or ens or tes).mp.
2. ("transcutaneous electric* nerve stimulation" or "transcutaneous nerve stimulation").mp.
3. ("electric* nerve stimulation" or "electrostimulation therap*" or "electro-stimulation therap*").mp.
4. ("electric* nerve therap*" or electroanalgesi* or electro-analgesi*).mp.
5. ("transcutaneous electric*" adj4 stimulat*).mp.
6. (amputat* or amputee*).mp.
7. (postamputation* or post-amputation*).mp.
8. ((phantom adj6 limb) or phantom-limb or stump*).mp.
9. (#4 or #1 or #3 or #2 or #5).
10. (#8 or #6 or #7).
11. (#10 and #9).

**Cochrane highly sensitive strategy for identifying randomized trials**

**in MEDLINE: sensitivity-maximizing version (2008 revision); Ovid format**

12. randomized controlled trial.pt.)
13. controlled clinical trial.pt.
14. randomized.ab.
15. placebo.ab.
16. drug therapy.fs.
17. randomly.ab.
18. trial.ab.
19. groups.ab.
20. or/12-19
21. (animals not (humans and animals)).sh.
22. 20 not 21
23. 22 and 11

## Appendix 2. CENTRAL search strategy

### The Cochrane Library search (Issue 1 2010)

1. “tens” or “al-tens” or “tns” or “ens” or “tes”:ti,ab,kw.
2. “transcutaneous electric* nerve stimulation” or “transcutaneous nerve stimulation” :ti,ab,kw.
3. “electric* nerve stimulation” or “electrostimulation therap*” or “electro-stimulation therap*” :ti,ab,kw.
4. “electric* nerve therap*” or electroanalgesi* or electro-analgesi* :ti,ab,kw.
5. “transcutaneous electric*” NEAR stimulation :ti,ab,kw.
6. (#1 OR #2 OR #3 OR #4 OR #5).
7. (amputat* or amputee*):ti,ab,kw.
8. (post-amputation* or postamputation*):ti,ab,kw.
9. (phantom-limb or (phantom NEAR limb) or stump* ):ti,ab,kw.
10. (fantom-limb or (fantom NEAR limb)):ti,ab,kw.
11. (#7 OR #8 OR #9 OR #10).
12. (#6 AND #11).
13. #12 Records from CENTRAL.

## Appendix 3. EMBASE search strategy

### EMBASE search via Ovid (1980 to Feb 2010)

[mp=title, abstract, subject headings, heading word, drug trade name, original title, device manufacturer, drug manufacturer name]
1. (tens or al-tens or tns or ens or tes).mp.
2. (“transcutaneous electric* nerve stimulation” or “transcutaneous nerve stimulation”).mp.
3. (“electric* nerve stimulation” or “electrostimulation therap*” or “electro-stimulation therap*”).mp.
4. (“electric* nerve therap*” or electroanalgesi* or electro-analgesi*).mp.
5. (“transcutaneous electric*” adj4 stimulat*).mp.
6. (amputat* or amputee*).mp.
7. (postamputation* or post-amputation*).mp.
8. ((phantom adj6 limb) or phantom-limb or stump*).mp.
9. (#4 or #1 or #3 or #2 or #5).
10. (#8 or #6 or #7).
11. (#10 and #9).

### Cochrane highly sensitive strategy for identifying randomized trials

### in MEDLINE: sensitivity-maximizing version (2008 revision); Ovid format

12. random*.ti,ab.
13. factorial*.ti,ab.
14. (crossover* or cross over* or cross-over*).ti,ab.
15. placebo*.ti,ab.
16. (doubl* adj blind*).ti,ab.
17. (singl* adj blind*).ti,ab.
18. assign*.ti,ab.
19. allocat*.ti,ab.
20. volunteer*.ti,ab.
21. CROSSOVER PROCEDURE.sh.
22. DOUBLE-BLIND PROCEDURE.sh.

23. RANDOMIZED CONTROLLED TRIAL.sh.
24. SINGLE BLIND PROCEDURE.sh.
25. or(/#12-#24).
26. ANIMAL/ or NONHUMAN/ or ANIMAL EXPERIMENT/.
27. HUMAN/.
28. (#26 and #27).
29. (#26 not #28).
30. (#25 not #29).
31. (#11 and #30).

## Appendix 4. PsycINFO search strategy

### PsycINFO search via Ovid (1806 to February 2010)

[mp=title, abstract, heading word, table of contents, key concepts]
1. (tens or al-tens or tns or ens or tes).mp.
2. ("transcutaneous electric* nerve stimulation" or "transcutaneous nerve stimulation").mp.
3. ("electric* nerve stimulation" or "electrostimulation therap*" or "electro-stimulation therap*").mp.
4. ("electric* nerve therap*" or electroanalgesi* or electro-analgesi*).mp.
5. ("transcutaneous electric*" adj4 stimulat*).mp.
6. (amputat* or amputee*).mp.
7. (postamputation* or post-amputation*).mp.
8. ((phantom adj6 limb) or phantom-limb or stump*).mp.
9. (#4 or #1 or #3 or #2 or #5).
10. (#8 or #6 or #7).
11. (#10 and #9).

## Appendix 5. AMED search strategy

### AMED via Ovid (Allied and Complementary Medicine) search (1985 to February 2010)

[mp=abstract, heading words, title]
1. (tens or al-tens or tns or ens or tes).mp.
2. ("transcutaneous electric* nerve stimulation" or "transcutaneous nerve stimulation").mp.
3. ("electric* nerve stimulation" or "electrostimulation therap*" or "electro-stimulation therap*").mp.
4. ("electric* nerve therap*" or electroanalgesi* or electro-analgesi*).mp.
5. ("transcutaneous electric*" adj4 stimulat*).mp.
6. (amputat* or amputee*).mp.
7. (postamputation* or post-amputation*).mp.
8. ((phantom adj6 limb) or phantom-limb or stump*).mp.
9 . (#4 or #1 or #3 or #2 or #5).
10. (#8 or #6 or #7).
11. (#9 and #10)

## Appendix 6. CINAHL search strategy

### CINAHL search (1982 to February 2010)

[ti,ab = title, abstract]
1. transcutaneous electrical nerve stimulation.
2. (tens OR al-tens OR tns OR ens OR tes).ti,ab.
3. ("transcutaneous electric* nerve stimulation" OR "transcutaneous nerve stimulation").ti,ab.
4. ("electric* nerve stimulation" OR "electrostimulation therap*" OR "electro-stimulation therap*").ti,ab.
5. ("electric* nerve therap*" OR electroanalgesi* OR electro-analgesi*).ti,ab.
6. ("transcutaneous electric*" adj4 stimulat*).ti,ab.
7. (#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR # OR #7).
8. exp AMPUTATION/ OR AMPUTATION STUMPS/.
9. (amputat* OR amputee*).ti,ab.
10. (postamputation* OR post-amputation*).ti,ab.
11. ((phantom adj6 limb) OR phantom-limb OR stump*).ti,ab.
12. PHANTOM LIMB/ OR PHANTOM PAIN/.
13. (#8 OR #9 OR #10 OR #11 OR #13).
14. (#7 AND #13).

## Appendix 7. Pedro search strategy

### Pedro search (1929 to February 2010)

[mp=title, abstract]
1. "transcutaneous electric* nerve stimulation".
2. ("electric* nerve stimulation" or "electrostimulation therap*" or "electro-stimulation therap*").mp.
3. ("electric* nerve therap*" or electroanalgesi* or electro-analgesi*).mp.
4. (amputat* or amputee*).mp.
5. (postamputation* or post-amputation*).mp.
6. "pain"
7. (#1 or #4 or #6).
8. (#1 and #4 and #6).

## Appendix 8. SPORTDiscus search strategy

### SPORTDiscus search (1975 to February 2010)

1. "tens" or "al-tens" or "tns" or "ens" or "tes":TX
2. "transcutaneous electric* nerve stimulation" or "transcutaneous nerve stimulation":TX
3. "electric* nerve stimulation" or "electrostimulation therap*" or "electro-stimulation therap*" :TX
4. "electric* nerve therap*" or electroanalgesi* or electro-analgesi* :TX
5. "transcutaneous electric* stimulation":TX
6. (#1 OR #2 OR #3 OR #4).
7. (amputat* or amputee*):TX
8. (post-amputation* or postamputation*):TX
9. (phantom-limb or (phantom NEAR limb) or stump* ):TX
10. (fantom-limb or (fantom NEAR limb)):TX
11. (#7 OR #8 OR #9 ).
12. (#6 AND #11).

13. (#6 AND #11) and “control trial”: TX

## WHAT’S NEW

Last assessed as up-to-date: 1 February 2013.

| Date | Event | Description |
|---|---|---|
| 5 March 2013 | Amended | No new studies available. To be assessed for updating in 2015 |

## CONTRIBUTIONS OF AUTHORS

Writing protocol - MM, A-MB, MJ, PM.

Writing full review - MM, A-MB, MJ, PM.

Search databases - MM, A-MB.

Study selection - MM, A-MB, MJ.

Assessment of methodological quality - MM, A-MB, MJ.

Data extraction - MM, A-MB, MJ.

Statistical analysis - MM, PM, A-MB, MJ.

Writing updates - MM, A-MB, MJ, PM

## DECLARATIONS OF INTEREST

None known

## DIFFERENCES BETWEEN PROTOCOL AND REVIEW

There are no differences between the protocol and the review.

## INDEX TERMS

### Medical Subject Headings (MeSH)

*Pain Management; *Transcutaneous Electric Nerve Stimulation; Amputation Stumps; Phantom Limb [*therapy]

## MeSH check words

Adult; Humans