Does neuromuscular electrical stimulation strengthen the quadriceps femoris: a systematic review of randomised controlled trials

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CRD summary
This review assessed the effects of neuromuscular electrical stimulation (NMES) on the strength of the quadriceps femoris. The authors concluded that limited evidence suggests that NMES can improve strength in comparison with no exercise, but volitional exercises appear more effective in most situations. This was a well-conducted review and the authors' cautious conclusions reflect the general poor quality of the included studies.

Authors' objectives
To determine whether neuromuscular electrical stimulation (NMES) increases the strength of the quadriceps femoris in adults.

Searching
MEDLINE, EMBASE, CINAHL, the Cochrane Controlled Trials Register and PEDro were searched up to July 2002 using the reported search terms. Studies were included regardless of the language of publication, publication date or journal.

Study selection
Study designs of evaluations included in the review
Randomised controlled trials (RCTs) or quasi-RCTs were eligible for inclusion. Crossover trials were excluded.

Specific interventions included in the review
Studies that compared a form of electrical stimulation (for the purpose of causing physiological changes in the muscle by means of the elicited contractions) with no treatment, sham treatment or volitional exercises were eligible for inclusion. Most of the included studies used isometric training with the knee flexed to 30 to 90 degrees over 4 to 6 weeks.

Participants included in the review
Studies of adults (aged over 18 years) were eligible for inclusion. There was no upper age limit for the participants. Studies of individuals with physical or psychological disorders affecting sensomotoric functioning were excluded. The included studies were in individuals with unimpaired and impaired quadriceps femoris muscles. Most of the included studies of impaired quadriceps muscles were in patients following anterior cruciate ligament repair; other studies involved elderly patients with arthrosis and patients with patello-femoral pain syndrome. Some studies enrolled only males, others enrolled only females, and some enrolled both sexes.

Outcomes assessed in the review
Studies that assessed maximum voluntary isometric strength or maximum voluntary isokinetic strength as primary or secondary outcomes were eligible for inclusion. The primary review outcome was isometric torque (in newton metres, Nm) measured by maximum volitional contractions at the end of training. The review also assessed the level of activity and participation.

How were decisions on the relevance of primary studies made?
One reviewer performed the initial search and first selection. Two reviewers then selected studies from complete papers, with any disagreements resolved by consensus.

Assessment of study quality
Studies were assessed and scored using criteria derived from the Delphi list: internal validity, generalisability and quantitative reporting of the outcomes (point estimates and variability). Internal validity covered randomisation methods, allocation concealment, baseline comparability of the treatment groups, blinding of assessors, carers or patients, and intention-to-treat analysis. Validity scores were then converted to percentages of the maximum score (9 points). Three reviewers independently assessed validity. Any disagreements were resolved by consensus, with the aid of three external reviewers where required.

Data extraction
Two reviewers independently extracted the data using standardised forms. The mean change from baseline between treatments was calculated with 95% confidence intervals (CIs) for each study, where possible. Not all studies reported data that enabled the mean change from baseline to be calculated, so variances of the follow-up scores for all the included studies were used to ensure comparable weighting in the meta-analysis.

Methods of synthesis
How were the studies combined?
The studies were grouped into subgroups (defined a priori) based on the characteristics of the participants (impaired or unimpaired quadriceps), type of NMES (superimposed or independent), time of application of NMES (during or post-immobilisation) and control (no exercise or volitional exercises). Studies that reported adequate data for NMES versus no exercise and NMES versus volitional exercises were pooled using a random-effects meta-analysis, and weighted mean differences (WMDs) with 95% CIs calculated. Other studies were combined in a narrative.

The potential for publication bias was assessed using a funnel plot, and the trim-and-fill method was used to assess the effects of 'missing trials'.

How were differences between studies investigated?
The studies were grouped as described above. Clinical heterogeneity among the studies was discussed with respect to patient characteristics, intervention and results. Statistical heterogeneity was assessed using the chi-squared test. Differences in the results among studies were examined using forest plots and heterogeneity explored further by graphical means. Meta-analyses were repeated using fixed-effect models. Further sensitivity analyses were conducted to examine the effects of a priori-defined validity criteria and statistical methods.

Results of the review
Thirty-five RCTs and quasi-RCTs were included (n=1,345).

Adults with unimpaired quadriceps femoris muscles (17 RCTs).

The mean quality score was 43% (range: 22 to 56).

NMES versus no exercise.

The funnel plot for all studies was asymmetrical, suggesting the possibility of publication bias.

Independent NMES versus no exercises (12 studies, n=235): all studies showed point estimates favouring NMES. The meta-analysis showed significant benefit with NMES compared with no exercise (WMD 8.00 Nm, 95% CI: 2.79, 13.21). Significant heterogeneity was found (P=0.0006).

Superimposed NMES versus no exercise (2 studies): one study showed significant improvement with NMES, while the other showed no significant difference between treatments. The pooled result was statistically significant in favour of NMES (WMD 25.61 Nm, 95% CI: 9.74, 41.75).

NMES versus volitional exercises (10 studies).

The funnel plot was asymmetrical, suggesting the possibility of publication bias.
Independent NMES versus volitional exercises (8 studies, n=155): the meta-analysis showed no significant difference between treatment groups (WMD -11.60 Nm, 95% CI: -24.34, 1.13). No significant heterogeneity was found (P=0.9).

Superimposed NMES versus volitional exercises (2 studies): the meta-analysis showed no statistically significant difference between treatment groups (WMD -11.11, 95% CI: -37.06, 14.83).

Results for independent versus superimposed NMES (2 studies), different frequencies of NMES (1 study), NMES in knee flexion versus extension (1 study) and NMES in knee flexion for different intensities (1 study) in unimpaired adults were also reported.

Adults with impaired quadriceps femoris muscles (18 studies).

The mean quality score was 40% (range: 11 to 67).

NMES versus no exercise.

Intervention applied post-immobilisation period (7 studies): all 3 studies presenting adequate data for display in a forest plot showed a non-statistically significant benefit with NMES compared with no exercise. All but one of the remaining 4 studies showed results favouring NMES. All of the studies had methodological weaknesses.

Intervention applied during the immobilisation period (3 studies): both studies presenting adequate data for display in a forest plot showed significant benefit with NMES; the remaining study showed no significant difference between treatments.

NMES versus volitional exercises. Intervention applied post-immobilisation period (5 studies): only one of 3 studies presenting adequate data for display in a forest plot that showed significant benefit with NMES used superimposed NMES; the other 2 studies used independent NMES. One of the two remaining studies only showed benefit over volitional exercises with medium frequency independent NMES; the results of the other favoured electromyographic-assisted volitional exercises.

Intervention applied during the immobilisation period (3 studies): one of the 2 studies presenting adequate data for display in a forest plot showed significant benefit with NMES compared with volitional exercises; the other showed no significant difference between treatments.

Results for experimental versus traditional NMES (2 studies) were also reported.

Authors’ conclusions
Limited evidence suggested that NMES can be more effective than no exercise in individuals with impaired and unimpaired quadriceps, but volitional exercises appeared more effective in most situations.

CRD commentary
The review question was clear in terms of the study design, intervention, participants and outcomes. Several relevant databases were searched, attempts were made to reduce publication and language bias, and the potential for publication bias was assessed. Methods were used to minimise reviewer errors and bias in the study selection, validity assessment and data extraction processes. Validity was assessed using established criteria, results were reported, and adequate information about the primary studies was given. The studies were appropriately grouped into pre-defined subgroups, and statistical and clinical heterogeneity were assessed and explored. Potential reasons for differences among the studies were also discussed.

This was a well-conducted review and the authors’ cautious conclusions correctly reflect the general poor quality of the included studies.

Implications of the review for practice and research
Practice: The authors stated that NMES may be preferred to volitional training during periods of immobilisation in a cast and, perhaps, where patients do not comply with advice about volitional training.

Research: The authors stated that further research is required to determine the effect of NMES on levels of clinical activity and participation, and to determine the optimal parameters for NMES.

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