Current aspects of assessment and treatment of dysphagia
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Chapter 7

The use of surface-EMG as biofeedback in the treatment of stroke patients with dysphagia: a systematic review

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Abstract
The use of surface EMG (sEMG) biofeedback has proven to be effective in different professions and patient groups, mainly in the rehabilitation of arm or leg function in stroke patients. The first publication on sEMG as biofeedback in swallowing rehabilitation was published as a case study in 1991. A systematic review was conducted to detect and compare all relevant studies to assess the quality of published articles on this topic and to investigate whether the use of sEMG biofeedback is effective in dysphagic stroke patients. A computer-assisted search was developed using the biomedical databases Pubmed, CINAHL and EMBASE. For assessing the quality of included articles the Physiotherapy Evidence Database-scale or PEDro scale was used. Forty-one articles were identified, of which six met our inclusion criteria. No randomized controlled trials were identified; all studies had a pre-treatment vs. post-treatment design. A total of 55 stroke patients are described in literature. Forty-seven patients were depended on non-oral feeding prior to the treatment. Thirty-three patients returned to an oral diet after treatment. The overall risk reduction ratio of the treatment of biofeedback in dysphagic stroke patients dependent on non-oral feeding was estimated to be 2.65 (95% CI: 1.81-3.86).
This review shows that the scarce literature on efficacy of sEMG biofeedback shows a potential benefit in favour of this treatment. Further research on the efficacy of sEMG-biofeedback in the treatment should clearly describe (randomized controlled) trials with clear treatment protocols on treatment intensity and type of exercise(s).
Introduction
An estimated 15 million people worldwide survive minor strokes each year; one in 450 people have a stroke every year. Stroke is a common cause for dysphagia. About 50% of stroke patients will suffer from swallowing disorders, like coughing and choking when eating and drinking.

In many patients swallowing function will recover in a short period (≤ 2 months) of time, but in a small group of patients total recovery of the swallowing function can take many months to several years.

In general, after a stroke, patients with swallowing problems will receive treatment by a speech pathologist in the acute care setting, like a stroke unit in an acute hospital. In the rehabilitation process following stroke, swallowing therapy is normally also provided by speech pathologists in rehabilitation centres, nursing homes and private practises. Swallowing function will recover in the majority of patients in a period of several months due to spontaneous recovery and swallowing therapy, but a large group will not recover from these problems within 3 months. In a recent study only 55% of patients returned to oral feeding after stroke. In other studies a recovery rate of 80% is reported. If swallowing does not recover, the patient will have to be fed through a feeding tube, in most cases a percutaneous gastro(jejuno)stomy will be placed by a surgeon. The incidence of patients not recovering from dysphagia after stroke, who are depend on tube feeding for maintaining adequate nutritional status, is estimated between 1.25% and 1.7%.

Although tube feeding is a necessary to maintain nutritional status, several studies suggest that tube fed stroke patients have a higher mortality than patients that stroke patients who eat and drink. This higher mortality rate is ascribed to a higher incidence of aspirationpneumonia, higher incidence of gastro-esophageal reflux and a higher rate of infections. Recent published studies, however, suggest that either treatment of these patients with surface electromyography (sEMG) as biofeedback might restore swallowing, allowing patients to return to normal eating and drinking.

Biofeedback is defined in short as "teaching patients with the help of electronic equipment to reveal physiological events". The rationale is that a patient, who sees his or hers muscle activity, will be able to train muscles better and faster than in a situation where the patient just feels the muscles contract.
The use of surface EMG biofeedback has proven to be effective in different professions and patient groups, mainly in the rehabilitation of arm or leg function in stroke patients. Although there are only few meta-analysis of studies or reviews published on the use of sEMG as a biofeedback tool in the treatment of stroke patients, the trend of the published meta-analyses and reviews directs to a positive treatment effect of EMG as biofeedback in stroke patients in the treatment of upper and lower extremities. The first publication on sEMG as biofeedback in swallowing rehabilitation was published as a case study in 1991. In swallowing rehabilitation sEMG is used by displaying the electrical activity of the submental muscles on a computer screen. Electrodes are therefore placed under the chin. The submental muscles are important for laryngeal elevation during swallowing and the sEMG-signal is proven to correlate with swallowing activity. Therapy consists mainly of one exercise (i.e. the Mendelsohn maneuver), where a patient is instructed to prolong a swallow and thus contracting his supralaryngeal and suprahypoidal muscles, which is visualized with sEMG. This maneuver was designed as a compensatory swallowing technique to clear residue from the pharynx, but has also shown to be effective as a rehabilitative exercise for restoring swallowing function.

All mentioned studies on swallowing rehabilitation and sEMG are relatively small in terms of sample size, and no definitive conclusions can be drawn. Therefore we conducted a systematic review to detect and compare all relevant studies to assess the quality of published articles on this topic and to investigate whether the use of sEMG biofeedback is effective in dysphagic stroke patients.

Methods
Search strategy and selection of articles
A computer-assisted search was developed and performed by two independent reviewers (HB, JK) using the biomedical databases Pubmed, CINAHL and EMBASE to identify all relevant articles published until from the initiation of the databases up to July 2008. Table 1 shows the relevant search strategies.
Table 1. Used search strategies

<table>
<thead>
<tr>
<th>Database</th>
<th>Search terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pubmed</td>
<td>Deglutition AND Deglutition Disorders AND Biofeedback AND Electromyography</td>
</tr>
<tr>
<td>CINAHL</td>
<td>Deglutition and Biofeedback and Electromyography</td>
</tr>
<tr>
<td>EMBASE</td>
<td>Deglutition AND Biofeedback</td>
</tr>
</tbody>
</table>

In addition to the use of the technique of reference tracing and inclusion of non-indexed studies known to the authors, initially no language limitations were used.

First studies were selected based on title and included those with the following criterion: describing the treatment effects of surface EMG as an adjunct to dysphagia therapy. From selected articles abstracts were reviewed and a further selection was made based on the criterion that the article should address adult stroke patients. Disagreements in the selection process were solved by discussion.

Quality assessment

For assessing the quality of included articles the Physiotherapy Evidence Database-scale or PEDro scale was used. The PEDro scale is based on the Delphi list developed by Verhagen et al. and is an 11-item scale designed for rating methodological quality of studies. Each satisfied item (except for item 1, which, unlike other scale items, pertains to external validity) contributes one point to the total PEDro score (range=0–10 points). A PEDro scale score of 4 points or higher is considered high quality, whereas studies with a score of 3 points or lower are considered lower quality. Table 2 shows the items on the PEDro scale.

Table 2. The PEDro-scale

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Eligibility criteria were specified.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Allocation was concealed.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>The groups were similar at baseline regarding the most</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Data analysis

Review Manager 5.0 (The Nordic Cochrane Centre, Copenhagen) was used for pooling of data of selected articles and testing the pooled data for heterogeneity. The same software package was used to calculate funnel plots to detect possible publication bias and to calculate a Forest-plot to determine an overall effect of the use of sEMG as biofeedback in the treatment of dysphagic stroke patients.

### Results

The Pubmed search yielded twenty-three references of which five were selected for review of their abstract based on the article title. Of these four articles, two articles\textsuperscript{25, 13} were excluded, because the first article focused on treatment of peptic ulcers and the second article did not include stroke patients. The other three articles were included in this review.

The search in CINAHL revealed fifteen articles of which fourteen were not identified by the previous Pubmed search. One abstract\textsuperscript{13} was selected for further reviewing. After reviewing the abstract it was excluded from our review because in this study an
accelerometer was used for biofeedback and not sEMG. The EMBASE search revealed one, previously not identified, reference which did not meet our inclusion criteria. A further three more articles were found by reference tracing and all three were included in this review. Table 3 shows the inclusion process of selected articles. Finally, a total of six articles were included for further quality assessment and statistical analysis.

Table 3. Inclusion of articles

<table>
<thead>
<tr>
<th></th>
<th>Pubmed</th>
<th>CINAHL</th>
<th>EMBASE</th>
<th>Reference tracing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of hits</td>
<td>23</td>
<td>15</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Previous not found in other database</td>
<td>23</td>
<td>14</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Number of selected abstracts</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Number of included studies</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Total included Studies (cumulative)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>

Data extraction from included articles

Finally six studies were included in this review and the full articles were reviewed for data. All included studies described relatively small groups of patients. Three included studies described only the effects of sEMG biofeedback in a stroke population. In two articles\textsuperscript{22,23} the patient groups were not homogeneous and a mixture of stroke patients and head-and-neck surgery patients were described in these articles. In the Huckabee-study\textsuperscript{16} three patients were included with dysphagia after a neurosurgical procedure. In all included articles the non-stroke patients were removed from our data files and the average time since stroke-onset was calculated for the stroke patients. In one study\textsuperscript{25} only data was provided since how many months the patient had dysphagia. In this review, this
data was considered to represent an indication for the amount of months post-onset of stroke. In one study no data was available of how many months post-onset of stroke the patients were at the beginning of their therapy. Furthermore, the number of patients depending on non-oral feeding (naso-gastric tube or PEG-tube) prior to sEMG biofeedback therapy was determined for further analysis.

In the six included articles a total of eighty-one patients are described of which are fifty-five stroke patients. Prior to the swallowing therapy with sEMG biofeedback, the majority of these patients were on non-oral feeding (85%, N=47). A total of thirty-three stroke patients with non-oral feeding recovered their swallowing ability after therapy and returned to a full oral diet (70%); fourteen patients remained dependent for non-oral feeding to maintain nutritional status. The data extracted from the included articles is presented in Table 4.

Table 4. Overview of included articles and patient data

<table>
<thead>
<tr>
<th>Study</th>
<th>Total number of included patients</th>
<th>Total number of included stroke patients</th>
<th>Average months since onset of stroke (SD, min-max)</th>
<th>Number of stroke patients on non-oral feeding at inclusion</th>
<th>Number of stroke patients on non-oral feeding after therapeutic intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bogaardt, 2009</td>
<td>11</td>
<td>11</td>
<td>33.1 (±42.4; 5-145)</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>Bogaardt, 2003</td>
<td>4</td>
<td>4</td>
<td>17.8 (±12.4; 5-32)</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Crary, 2004</td>
<td>45</td>
<td>25</td>
<td>24.8</td>
<td>20</td>
<td>9</td>
</tr>
<tr>
<td>Crary, 1995</td>
<td>6</td>
<td>6</td>
<td>18.8 (±18.0; 5-54)</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Huckabee, 1999</td>
<td>10</td>
<td>7</td>
<td>31.6 (±29.0; 8-84)</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Stanschus, 2002</td>
<td>5</td>
<td>2</td>
<td>N/A</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>total</td>
<td>81</td>
<td>55</td>
<td>26.2</td>
<td>47</td>
<td>14</td>
</tr>
</tbody>
</table>

1 = study also describes twenty patients after head-and-neck surgery
2 = only the average number of months with dysphagia is described in article
3 = study also includes three patients with dysphagia after neurosurgery
Quality assessment of included studies

This review included six articles; none of the articles described a randomized controlled trial. All six articles described baseline and post therapy swallowing problems in their patients.

The PEDro scale was used to assess the methodological quality of these included articles. In only three articles the criteria for eligibility for enrolling this therapy is described; in the other articles it remains unclear why the patient was treated with sEMG biofeedback as an adjunct to dysphagia therapy and selection bias cannot be ruled out. Two studies did not describe point measure of the size of the treatment effect nor did they present “measures of variability”, like standard deviations, confidence intervals etcetera. None of the included studies reported that the assessor was blinded for the therapy outcome, which does not rule out observer bias in these studies.

PEDro scores ranged from two to four, where only four articles (Bogaardt et al., 2009; Crary et al., 2004; Crary, 1995; Huckabee & Cannito, 1999) reached the 4-point level, indicating a high quality study.

Table 5. PEDro scale scores of included articles

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Eligibility criteria</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2. Random allocation</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3. Concealed allocation</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4. Similar baseline</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
None of the selected studies has used a control group of patients to compare the treatment results. The role of spontaneous recovery of swallowing function cannot be ruled out in many cases. Looking at the patient’s data as presented in the articles, most neurological patients can be considered as chronic patients, where no spontaneous recovery is to be expected. In three articles (Bogaardt et al., 2009; Bogaardt, 2003; Huckabee & Cannito, 1999)\textsuperscript{14,18,16} is clearly described that treated patients where patients, who did not experience any functional benefit from previous received conventional speech therapy. Only one study (Huckabee & Cannito, 1999)\textsuperscript{16} describes the therapeutic intensity (i.e. sessions per week, time per session) rather clearly. Other studies remain unclear on treatment intensity.

Clinical treatment outcome-measures differ from article to article. Outcome measures using a surrogate outcome, like oropharyngeal swallowing efficiency, is used in the Stanschus study\textsuperscript{23}. Patient related outcome measures, like the Functional Oral Intake Scale are used in

<table>
<thead>
<tr>
<th>5. Blinding patients</th>
<th>-</th>
<th>-</th>
<th>-</th>
<th>-</th>
<th>-</th>
<th>-</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Blinding therapist</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7. Blinding assessor</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8. Outcome &gt; 85%</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>9. Intention to treat</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>10. Between group comparison</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>11. PM / MoV\textsuperscript{2}</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

\textsuperscript{1} = criterion is not used for calculating the PEDro score (Maher, 2003)
\textsuperscript{2} = PM: point measure; MoV: measure of variability
other studies (Crary, 2004; Bogaardt et al., 2009). One study uses an outcome scale which cannot be considered clinimetrically valid (Huckabee & Cannito, 1999). None of the studies measures therapeutic outcomes both on a functional level as on a level from the patients’ perspective.

**Meta-analysis of included articles**

Due to the differences in therapy outcomes in included articles the most robust difference between pre treatment and post treatment dysphagia severity reported in all six studies was chosen, i.e. the number of patients dependent for non-oral feeding prior to treatment against the number of patients who returned to oral feeding after treatment. This data is previously described in Table 4.

Comparing the number of non-orally fed patients before treatment to the number of patients non-orally fed after treatment provides a “Risk Ratio” (i.e. risk reduction) of each study as an estimated overall effect-size for the specific intervention in the study. The Risk Ratios of all included studies were calculated by using Review Manager 5.0 and are presented in Table 6. The data was formally tested for heterogeneity ($t^2=0.00; \chi^2=2.71, df=5 (p=0.74); I^2=0\%$) showing no heterogeneity in our data, allowing an estimation of an overall effect of the intervention. Based on the data derived from selected articles, the overall risk ratio of the treatment of biofeedback in dysphagic stroke patients dependent on non-oral feeding was estimated to be 2.65 (95% CI: 1.81-3.86), using a random effects model. Using a fixed effects model the estimated ratio was 2.94 (95% CI: 1.98-4.37). An additional funnel plot was conducted and revealed no publication bias in this data set.

Table 6 presents the meta-analysis of included data. Based on the data derived from the selected articles the number-needed-to-treat is equal to 1.6.
### Table 6. Meta-analysis of included data

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>pre therapy Events</th>
<th>Total Events</th>
<th>post therapy Events</th>
<th>Total Events</th>
<th>Weight</th>
<th>Risk Ratio M-H, Random, 95% CI</th>
<th>Risk Ratio M-H, Random, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bogaardt 2003</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>3</td>
<td>2.1%</td>
<td>7.00 [0.51, 96.06]</td>
<td></td>
</tr>
<tr>
<td>Bogaardt 2008</td>
<td>9</td>
<td>9</td>
<td>2</td>
<td>9</td>
<td>12.2%</td>
<td>3.80 [1.29, 11.22]</td>
<td></td>
</tr>
<tr>
<td>Crary 1995</td>
<td>6</td>
<td>6</td>
<td>1</td>
<td>6</td>
<td>7.0%</td>
<td>4.33 [1.03, 18.17]</td>
<td></td>
</tr>
<tr>
<td>Crary 2004</td>
<td>20</td>
<td>20</td>
<td>9</td>
<td>20</td>
<td>63.4%</td>
<td>2.16 [1.34, 3.47]</td>
<td></td>
</tr>
<tr>
<td>Huckabee 1999</td>
<td>7</td>
<td>7</td>
<td>2</td>
<td>7</td>
<td>13.2%</td>
<td>3.00 [1.06, 8.52]</td>
<td></td>
</tr>
<tr>
<td>Stanescus 2002</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>2.2%</td>
<td>5.00 [0.30, 66.01]</td>
<td></td>
</tr>
<tr>
<td>Total (95% CI)</td>
<td>47</td>
<td>47</td>
<td>100.0%</td>
<td></td>
<td></td>
<td>2.65 [1.81, 3.86]</td>
<td></td>
</tr>
</tbody>
</table>

Total events 47

Heterogeneity: \( \text{Tau}^2 = 0.00; \text{Chi}^2 = 2.71, \text{df} = 5 (P = 0.74); \text{I}^2 = 0\%

Test for overall effect: \( Z = 5.04 (P < 0.00001) \)
Discussion

For this review we identified six articles on the treatment effects of sEMG biofeedback in the treatment of dysphagia in stroke patients. No randomized controlled trials were identified; all studies had a pre-treatment vs. post-treatment design (i.e. case-series). All included articles report good therapy outcomes. The question arises whether the use of sEMG biofeedback in the treatment of stroke patients is more effective than other interventions.

Mann et al.\(^5\) reported that in 128 acute stroke patients of which 64% had dysphagia. Six months after their stroke 87% of this cohort returned to their pre-stroke diet. Recovery of swallowing function in this cohort is described to be the result of spontaneous recovery and rehabilitative interventions\(^5\).

In our meta-analysis a total of forty-seven stroke patients on a non-oral diet were included. Thirty-three patients recovered swallowing ability and returned to a full oral diet; fourteen patients did not show progress on their swallowing function. Thus, overall 70% of all patients improved from non-oral to an oral diet. This percentage is lower than the outcome reported in the Mann-study. In our meta-analysis the average time post-stroke however was 26.2 months, thus all included patients can be considered to be chronic dysphagic. It is very unlikely that spontaneous recovery had any influence on our included population. This suggests that the use of sEMG biofeedback has a strong therapeutic effect in stroke patients.

Unfortunately, there are no studies available on the effects of sEMG biofeedback in the acute stroke population. One might suggest that if sEMG biofeedback is effective in chronic stroke patients, this effect will also be applicable to acute stroke patients with dysphagia. A large randomized controlled trial would be necessary to study these effects of sEMG biofeedback in the acute population. The question arises whether such a trial can be set up because a very large number of patients will have to be included because the data has to be corrected for spontaneous recovery.

The patients in selected studies can be considered chronic dysphagic after stroke, suggesting that any progress in swallowing function could be related to the use of sEMG as an adjunct in dysphagia therapy. Unfortunately the included studies do not clearly describe the treatment frequency and treatment intensity of which patients were subjected to. Training
of muscle strength and muscle coordination in stroke patients is considered to be highly
dependent on the intensity and frequency of treatment\textsuperscript{24}. The influence of differences in
treatment intensity and frequency between included studies cannot be ruled out. There are
also differences in the way patients were instructed to do some exercises, when reported in
the articles. In the Crary-study\textsuperscript{22} and the Bogaardt-study\textsuperscript{14} both patient groups are
instructed to make a Mendelsohn maneuver, however in the latter study patients are
instructed to maintain muscle contractions for ten seconds, where in the first study patients
are instructed to maintain muscle contraction for three to five seconds.
Furthermore, in the described treatment in the articles often is seen that also another range
of rehabilitative exercises are introduced during the sessions, so that any given result cannot
be solely described to the use of sEMG as biofeedback in combination with one exercise.

Further research on the efficacy of sEMG-biofeedback in the treatment should clearly
describe (randomized controlled) trials with clear treatment protocols on treatment
intensity and type of exercise(s). Also further research should establish whether sEMG-
biofeedback in combination with the Mendelsohn maneuver alone is a sufficient and
effective treatment for chronic dysphagic patients or that a combination with other
exercises is more effective.

Conclusion
This review shows that the scarce literature on efficacy of sEMG biofeedback shows a
potential benefit. Six articles were identified on the efficacy on this adjunct to therapeutic
intervention. A total of 55 stroke patients are described in literature. Described patients can
be considered to be chronic dysphagic; forty-seven patients were depended on non-oral
feeding prior to the treatment. Thirty-three patients returned to an oral diet after
treatment.
Surface EMG as biofeedback in the treatment of chronic dysphagia after stroke is an
effective adjunct to standard therapy for swallowing disorders. Critical appraisal of
existing literature however shows the need of setting up randomized controlled trials, with
clear treatment protocols and treatment intensity, in this area of dysphagia treatment in the
near future, to provide even more valid evidence on the efficacy and efficiency of sEMG-
biofeedback in the treatment of dysphagic patients.
References


