Skill training in the treatment of dysphagia: Application of an sEMG-biofeedback protocol in a single-case intervention study

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Introduction:

Patients with dysphagia experience a substantial limitation in their quality of life, thus, an intensive functional treatment is essential for the recovery of oral nutrition. Many approaches in functional dysphagia rehabilitation, however, are not effective in dysphagic individuals due to their limited abilities to use proprioceptive feedback for sensorimotor skills (Böhme 2010, Boogaardt 2009a). Intervention protocols including visual biofeedback methods are well suited for the treatment of these patients, as the simultaneous visual and proprioceptive feedback supports motor learning (Huckabee 1997).

Since Crary's (1995) study about the application of sEMG (surface electromyography)-Biofeedback in dysphagia therapy, there have been several studies confirming the utility of the method for the rehabilitation of swallowing disorders (e.g. Huckabee & Cannito 1999, Crary et al. 2004). So far, most studies focused on the application of sEMG biofeedback as a method to facilitate muscle strength e.g. during the execution of compensatory swallowing maneuvers ('effortful swallow', 'Mendelsohn maneuver' and others) (see Steele et al. 2012 for an overview). Sella (2012), however, postulates that dysphagia is not always due to a deficit in muscle strength, but can rather be attributed to limited precision and timing of muscular activation, thus, a limitation of swallowing skill, rather than strength. Likewise, Crary and Baldwin (1997) reported inefficient and overactivation of muscle activity in patients performing strength tasks, while Robbins et al. (2008) argue that particularly the ability to coordinate muscular strength is the basis for improvements in swallowing function. Following this rationale, more recent studies showed that biofeedback-protocols with a focus on the training of fine-tuned swallowing skills, rather than strength training, are effective in the treatment of patients with chronic dysphagia (Athukorala et al. 2014, Huckabee & Macrae 2014). The aim of this study was to investigate the effectiveness of a specific skill-based sEMG-biofeedack treatment protocol for a stroke patient with chronic dysphagia.

Methods

Application of sEMG biofeedback in dysphagia therapy

The application of sEMG biofeedback in the treatment of lingual function implies the attachment of skin electrodes that record the activity of target muscle groups, specifically the suprahyoidal muscles: M. digastricus, M. stylohyoideus, M. mylohyoideus. By connecting the sEMG recording device with a computer and special software, the muscle activity is displayed on a computer screen (by a 'plotline'), so that the patient can observe and directly modify the movements of the target muscles according to the respective task (Boogardt 2009a, Schultheiss 2013), e.g. increasing the force of his movements and by this achieving a rise of the plotline. The swallowing-related plotline is characterized by a rise for about 2 seconds with one or two peaks at the point of the maximum muscular activity (Boogardt, Grolman & Fokkens, 2009, Ding et al. 2000) *(fig 1).* One frequent application of the sEMG biofeedback method is to instruct the patient to actively activate his target muscular function, so that the plotline hits a pre-defined training threshold or target.

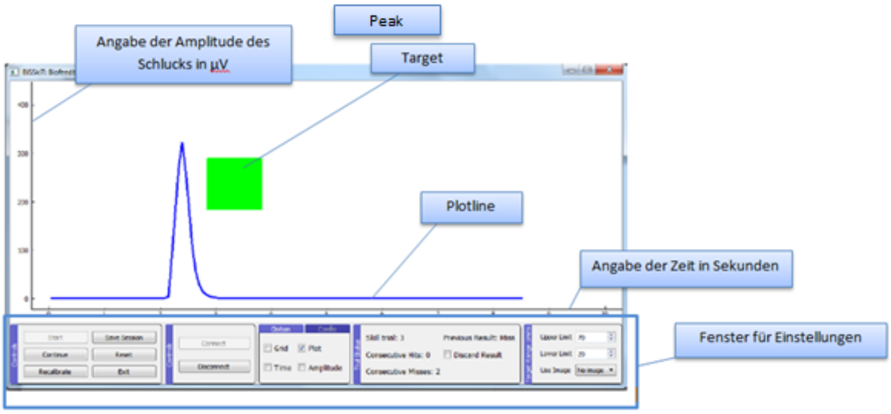

Fig 1: Screen of the BiSSkiT-Programme (Rose Centre for Stroke Recovery and Research, 2014 (S.18), modified figure)

The goal of a 'skill-based' training is to improve coordinated and well-timed muscular activation. By his, neurophysiological correlates that control fine motor skills are enforced by high -frequent functional repetitive training with direct (visual) feedback through the application of principles of motor learning (Huckabee & Macrae 2014). These objectives are implemented in the BiSSkiT-Programme (Biofeedback in Strength and Skill Training Programm; The University of Canterbury Rose Centre for Stroke Recovery and Research, 2014), a computer software for the application of sEMG Biofeedback in strength and in skill training for individuals with dysphagia. The programme provides visual targets on the computer screen (e.g. a green box, *fig 1*) in two conditions: 1**. static targets** (BiSSkiT assessment mode): the green box maintains the same size and position on the screen**; 2. dynamic targets** (BiSSkiT training mode): the green box varies in size and position in relation to the patient's performance.

Research objective

The objective of the current study was to develop and evaluate a patient-oriented protocol for an intensive skill – based treatment of dysphagia in a chronic stroke patient with mild-moderate oropharyngeal dysphagia. After a training phase of three weeks including 12 training sessions, the patient should be able to swallow a 2ml water bolus voluntarily and with well-coordinated muscle strength. As a functional result, a reduction of saliva drooling and posterior leaking was expected. The training protocol was conducted as a high intensive skill training supported by visual sEMG Biofeedback provided by the BiSSkiTprogramme.

The analysis of the effectiveness of the treatment protocol was based on the following research questions:

1. Does the application of a sEMG Biofeedback protocol over 12 training sessions lead to an improvement with respect to the initiation and inhibition (timing) and additionally with

respect to the adaptation of the range of movements (strength) during swallowing of a 2ml water bolus?

2. Do potential positive effects of the protocol lead to an improvement of functional abilities of the patient during eating and to improvements of self-reported quality of life?

Participant

The 73-years-old female participant reported mild to moderate dysphagic symptoms 14;3 years after a stroke, including prolonged bolus retention within the oral cavity before swallowing and occasional penetration and aspiration events. Due to these symptoms the patient experienced an increasing fear of swallowing and a high level of distress during mealtimes. During clinical swallowing examination the patient was not able to initiate a voluntary swallow, neither self-initiated nor by instruction. Additionally, the patient was aphasic with good language comprehension and moderate apraxia of speech.

Treatment protocol

The study was conducted in an ABA study design (*fig. 2).* In the pre- and post- intervention baseline measures (A) the patient performed a total of 30 swallows with three different boluses:

- ⇨ voluntary saliva swallows
- ⇨ assisted saliva swallows (a minimal amount of water was applied to the tongue)
- ⇨ 2ml water bolus.

With each bolus type, the first 5 swallows were performed with visual biofeedback provided by the BiSSkiT programme with a static target (BiSSkiT assessment mode) and another 5 swallows were performed with visual biofeedback by the BiSSkiT programm providing dynamic targets (BiSSkit training mode).

Outcome measures were the number of correctly initiated swallows (timing) and the number of correctly initiated swallows with adequate muscle strength (timing and strength) in the two target conditions (static vs. dynamic targets).

To identify possible changes in the patient's self-reported quality of life, the German version of the SWAL QoL (McHorney et al. 2000, Prosiegel, Wagner-Sonntag & Koch, 2006 in: Stanschus 2006) was conducted in both baseline measurements before and after the treatment.

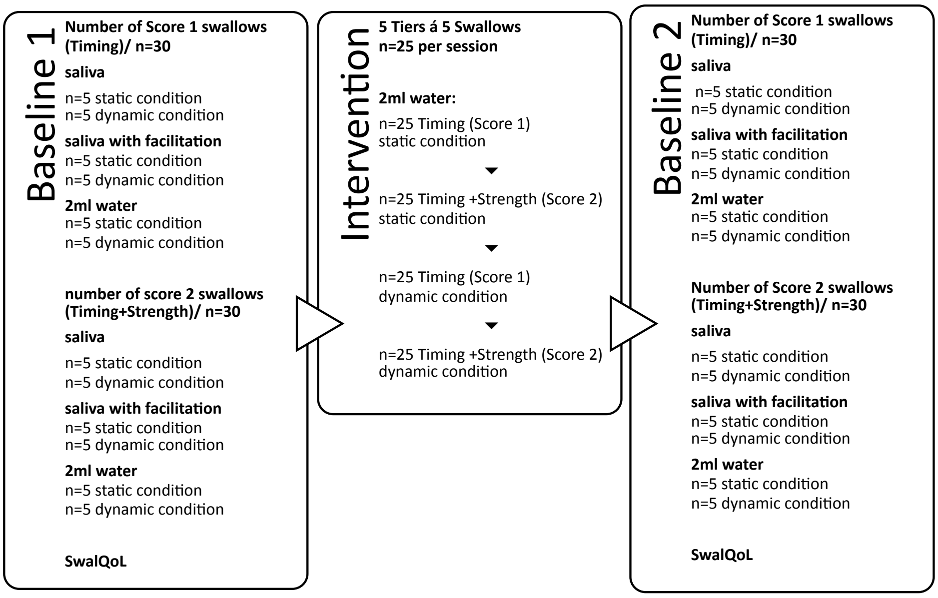

Fig 2: ABA study design

The treatment phase (B) comprised 12 training sessions, each including 5 blocks á 5 swallows. The sEMG biofeedback treatment was performed with the BiSSkiT programme, first in the easier ‘assessment mode’ of the programme (static target), later with the more difficult ‘training mode’ of the programme (dynamic target). Each of the 12 training sessions began with a habituation phase after proper attachment of the sEMG recording devices. After habituation the patient performed 5 swallows with a 2ml water bolus.

All swallows performed by the patient were rated according to the following scoring system:

Score 0= the swallowing-plotline does not hit the target (*fig 3*)

Score 1= the swallowing-plotline hits the target (correct timing)

Score 2= the swallowing- plotline hits the target and stays within the upper and lower limit of the target (correct timing and strength) (*fig 4*).

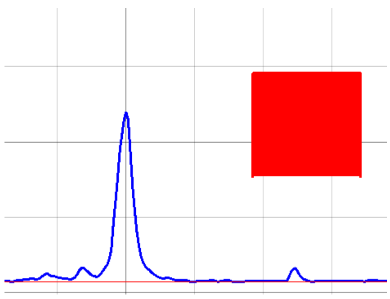

fig 3: swallow plotline outside the target (Score 0)

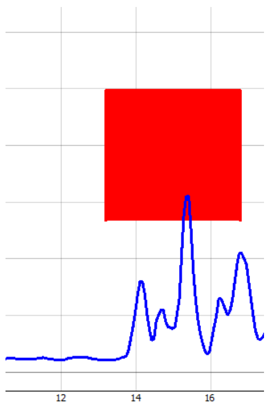

fig 4: swallow plotline within the limits of the target (Score 2)

Data analysis:

The data elicited in the baseline measurements was analyzed with respect to the number of swallows with adequate timing (score 1) and the number of swallows with adequate timing and strength (score 2) within the two target conditions (static target vs. dynamic target). McNemar`s Chi Square test, one-tailed, was applied for these comparisons.

Results:

The number of swallows with adequate ***timing*** (score 1) increased significantly across both target conditions (static and dynamic target) from 0 to 17 swallows after treatment (*p*= .000, McNemar, one-tailed) (*table 1*). This significant increase was also evident for both individual target conditions with an increase in the static condition from 0 to 10 correct swallows (*p*= .002, McNemar, one-tailed) and an increase in the dynamic condition from 0 to 7 correct swallows (*p*= .012, McNemar, one-tailed).

Table 1 Comparison of swallows with adequate timing (score 1) during pre- and post intervention baseline measures in the static target vs. dynamic target condition and across both conditions

	BL1	BL2	
static; n=15	0	10	*p*=.002*[1]
dynamic; n=15	0	7	*p*=.012*
both: n=30	0	17	*p*=.000*

A significant increase of swallows with adequate ***timing and strength*** (score 2) was also found with an improvement from 0 to 9 correct swallows across both target conditions (static and dynamic target) (*p*= .004, McNemar, one-tailed) that was confirmed by a significant improvement from 0 to 6 correct swallows in the static condition (*p*= .021, McNemar, one-tailed). The number of swallows with correct timing and strength did not change significantly in the dynamic target condition (*p*= .12, McNemar, one-tailed). (*table 2*)

Table 2 Comparison of swallows with adequate timing and strength (score 2) during pre- and post intervention baseline measures in the static target vs. dynamic target condition and across both conditions

	BL1	BL2	
static; n=15	0	6	*p*=.021*
dynamic; n=15	0	3	*p*=.12
both: n=30	0	9	*p*=.004*

1 * statistisch signifikanter Unterschied mit p < .5

With respect to changes in self-reported quality of life the patient indicated improvements in 20 aspects elicited in the SWAL QoL-questionnaire, including a reduction of penetration and aspiration and a reduced fear of swallowing and distress during mealtimes.

Conclusions:

The aim of this study was to investigate the effectiveness of a skill-oriented sEMG-based treatment protocol in the treatment of a stroke patient with chronic dysphagia. After 12 treatment sessions with sEMG biofeedback provided by the BiSSkiT software the participant was able to improve her ability to initiate a swallow with adequate timing significantly. This improvement was evident when the swallow target was static (and thus predictable), as well as when the swallow target was dynamic and varying in location and size. Furthermore, the patient could modulate her muscular strength significantly better during voluntarily initiated swallows with the swallow-triggering target in a static position. For swallows elicited by a dynamic target, this level of skill modulation, however, could not be improved significantly.

In summary, the application of the sEMG Biofeedback protocol with the BiSSkiT programme led to an improvement with respect to the initiation and with the adaptation of the range of movements during swallowing. This improvement is linked to improvements in quality of life reported by the patients, particularly to a reduction of aspiration events and fear of swallowing.

The interpretation of the study's results are limited by a lack of normative control data from healthy participants with respect to their ability to perform successful swallows in the training protocol that was used in this study. Furthermore, the application of a control task would have been beneficial for the interpretation of the results as being directly related to the intervention. The introduction of a specific scoring system for the interpretation of the patient's swallowing performance relating to timing and combined timing and strength, however, proved to be useful as this allowed a more specific interpretation of the treatment outcome with respect to different levels of skilled swallowing.

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