연하장애 치료 어디까지 왔을까

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강의에 앞서

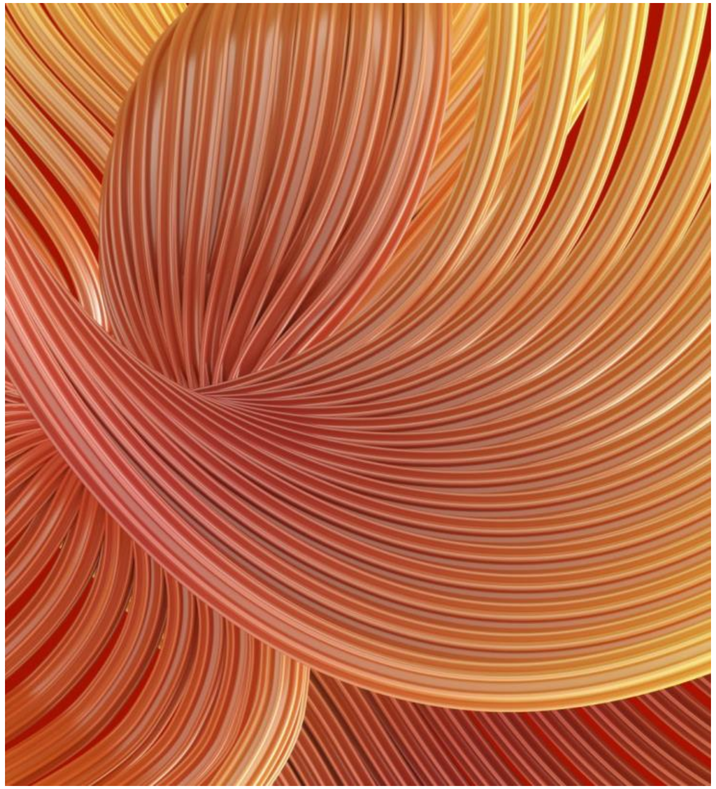
Neurogenic dysphagia, Oropharyngeal dysphagia

2018-2021 Original article, Systematic review/Meta-Analysis

Clinical application

Known strategies: evidence put forward

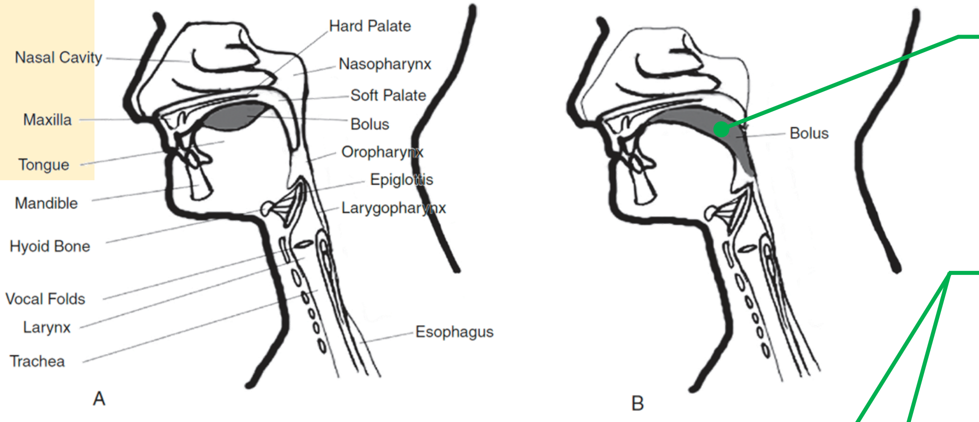
Some newer strategies



Therapeutic Strategies for Dysphagia

- Exercise
- Peripheral Electrical Stimulation
- Neuromodulation

Compensatory Strategy & Swallow Exercise

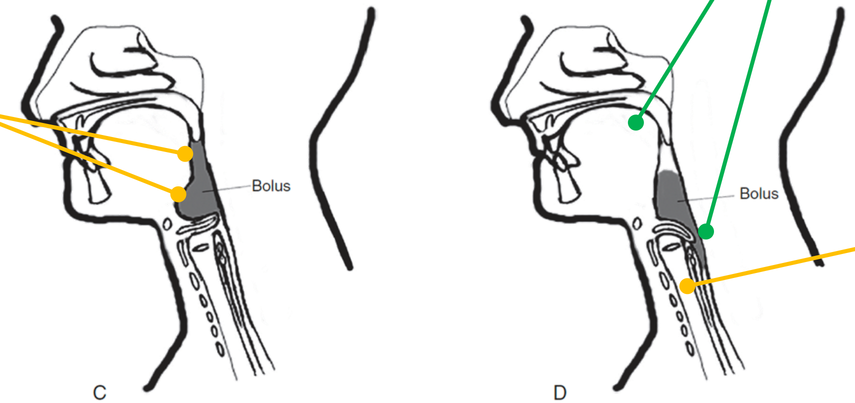


- Oral bolus hold
  : to reduce premature spillage and reduce swallow response delay

- Masako maneuver
  : tongue base and pharyngeal wall contact
  : bolus propulsion

- Effortful swallow
  : tongue base retraction
  : pharyngeal constrictor contraction

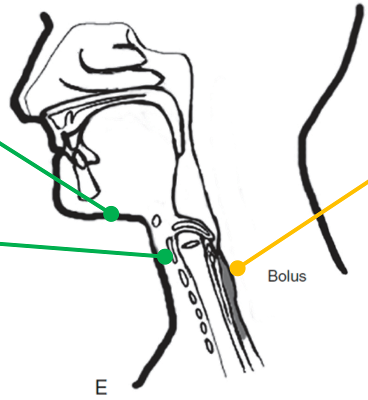
- Chin tuck posture
  : widening the vallecular space
  : positioning base of tongue closer to posterior pharyngeal wall



- Super-supraglottic swallow
  : voluntary airway closure before the swallow

- Shaker exercise
  : UES opening by suprahyoid muscles

- Mendelsohn maneuver
  : anterior upward laryngeal motion
  : laryngeal closure & UES opening

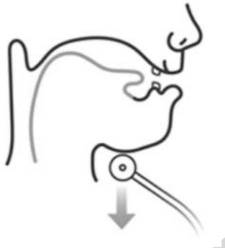


- Multiple swallows
- Liquid wash

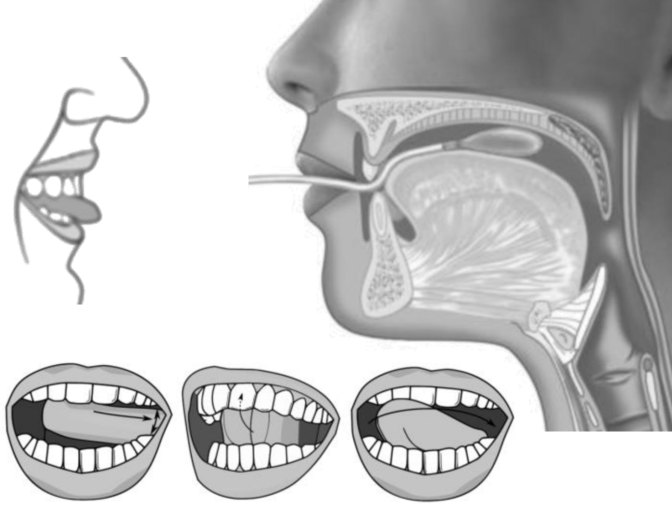
Braddom 6th ed.

Types of Swallow Exercise

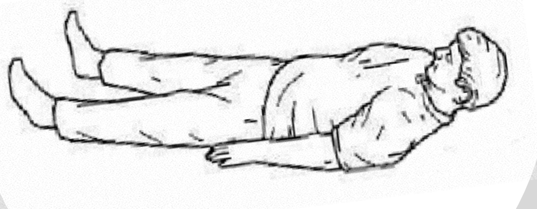
- Chin tuck against resistance (CTAR) exercise
- Shaker exercise
- Effortful swallowing
- Biofeedback
- Expiratory muscle strength training (EMST)
- Lingual exercise



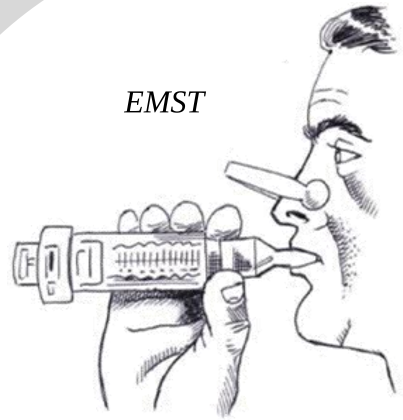
CTAR



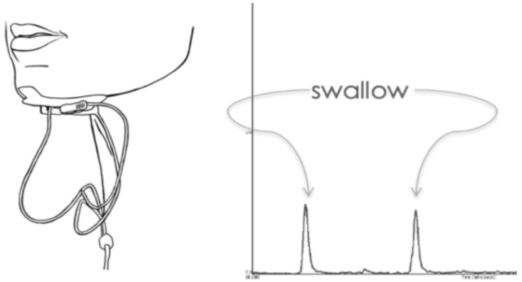
Lingual / Tongue-base retraction exercise



Shaker

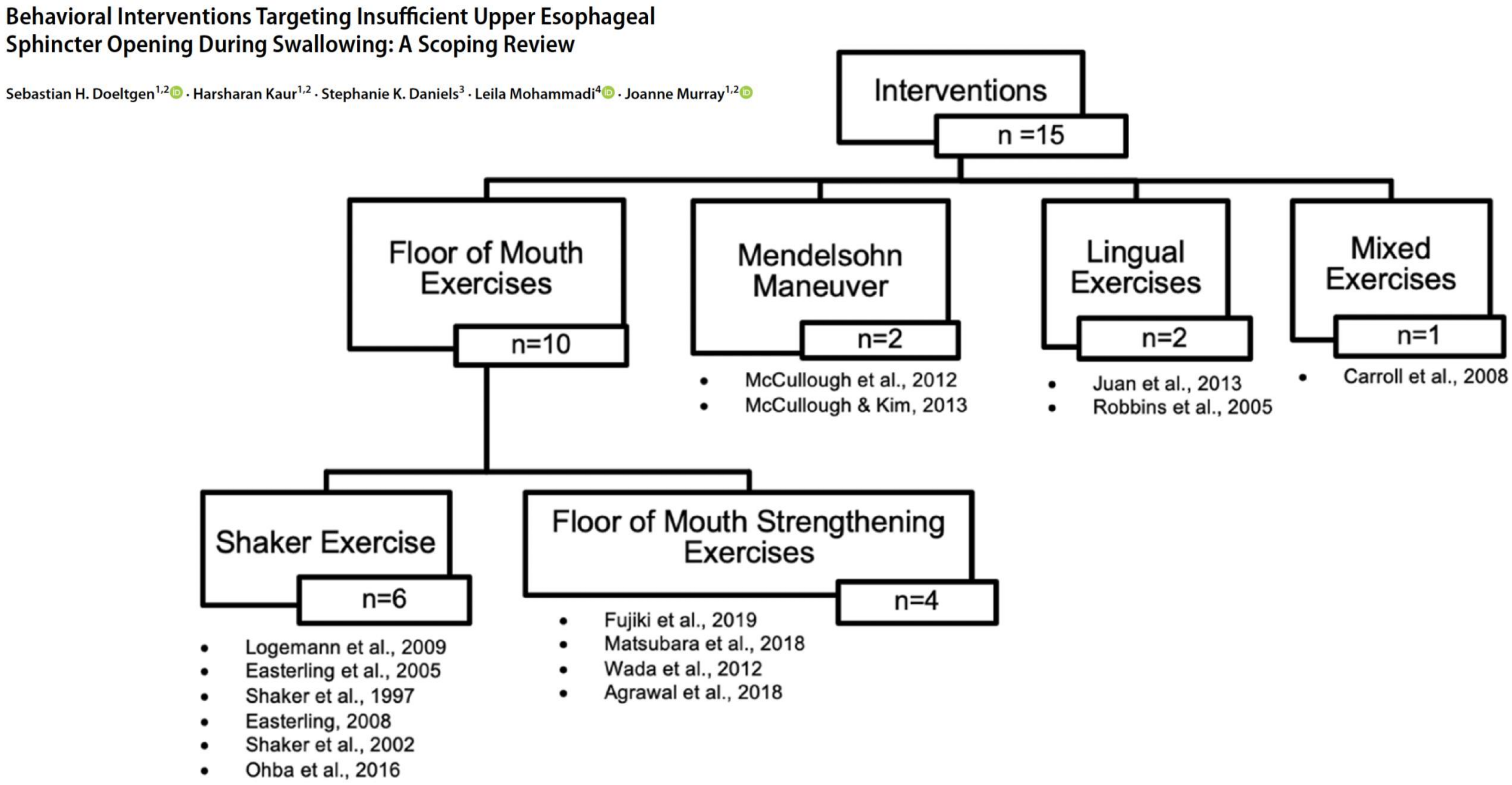


EMST



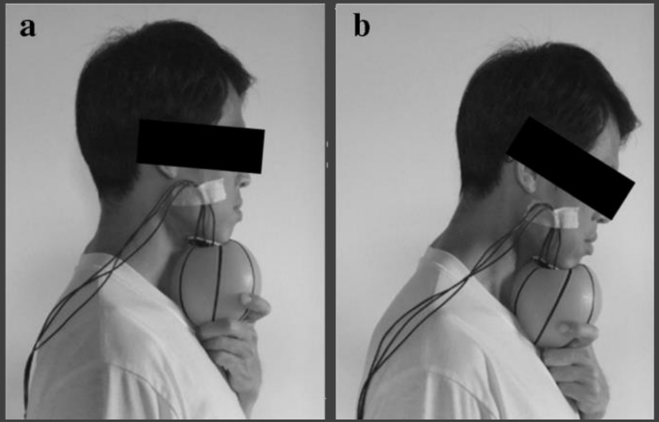
EMG biofeedback

Exercise for Upper Esophageal Sphincter Opening



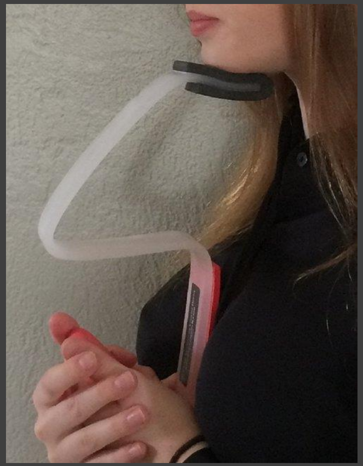
S. H. Doeltgen et al. Dysphagia (2021) August. https://doi.org/10.1007/s00455-021-10349-6

Chin tuck against resistance (CTAR) exercise



Chin Tuck Against Resistance (CTAR): New Method for Enhancing Suprahyoid Muscle Activity Using a Shaker-type Exercise

Dysphagia (2014) 29:243–248



PhagiaFLEX™

https://www.alternativespeech.com

Chin tuck against resistance exercise for dysphagia rehabilitation: A systematic review

- CTAR exercise more selectively activates the suprahyoid muscle and improves swallowing function.
- It is less strenuous than Shaker exercise, it requires less physical burden and effort, allowing greater compliance.

Park JS. J Oral Rehabil. 2021;48:968–977

Effects of chin tuck against resistance exercise *versus* Shaker exercise on dysphagia and psychological state after cerebral infarction

Jing GAO [1], Hui-Jun ZHANG [2] *

CTAR exercise can significantly relieve depression and has the similar effect on improving swallowing function as compared with Shaker group.

TABLE III.—*Comparison of VFSS scores in the three groups before and after intervention (mean±SD).*

Time point	Control group	Shaker group	CTAR group	χ^2 / *F* value	P value
Pre-intervention	5.00±1.51	5.30±1.64	5.30±1.47	0.54	0.76
2-week intervention	4.90±1.37	4.60±1.59	4.53±1.61	1.05	0.36
4-week intervention	4.30±1.82	3.17±1.84* †	3.13±2.13* †	7.17	0.00
6-week intervention	4.23±1.88	2.87±1.94* †	2.77±2.22* †	6.54	0.00

CTAR: chin tuck against resistance exercise; Shaker: Shaker exercise.
*P<0.05 compared to pre-intervention and 2-week intervention in Shaker and CTAR groups; † P=0.00 compared to control group.

TABLE VIII.—*Comparison of SDS scores amongst the three groups (mean±SD).*

	Control group	Shaker group	CTAR group	χ^2 / *F* value	P values
Pre-intervention	48.87±6.010	49.20±6.06	49.17±6.42	0.51	0.77
6-week intervention	48.20±6.62*	44.80±4.66 † §	42.47±4.22 † # $	8.98	0.00

SDS: Self-Rating Depression Scale; CTAR: chin tuck against resistance exercise; Shaker: Shaker exercise.
*P=0.68 and † P=0.00 for pre-intervention *vs.* 6-week intervention in the same group; § P=0.03 and # P=0.00 compared to control group after 6-week intervention; $ P=0.00 compared to Shaker group after 6-week intervention.

European Journal of Physical and Rehabilitation Medicine 2017 June;53(3):426-32

Cervical isometric exercises improve dysphagia and cervical spine malalignment following stroke with hemiparesis: a randomized controlled trial

Avraam PLOUMIS *, Soultana L. PAPADOPOULOU, Stavroula J. THEODOROU, George EXARCHAKOS, Panagiotis GIVISSIS, Alexander BERIS

European Journal of Physical and Rehabilitation Medicine 2018 December;54(6):845-52

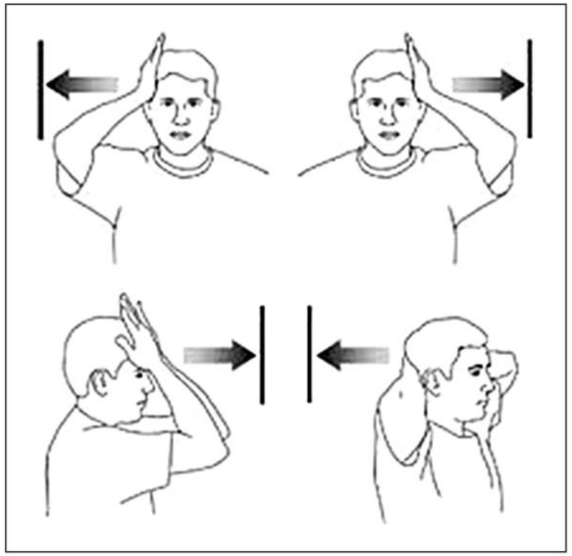


Figure 2.—Isometric cervical exercises were performed in all 4 directions.

Led to more significant correction of cervical alignment and more pronounced improvement in swallowing.

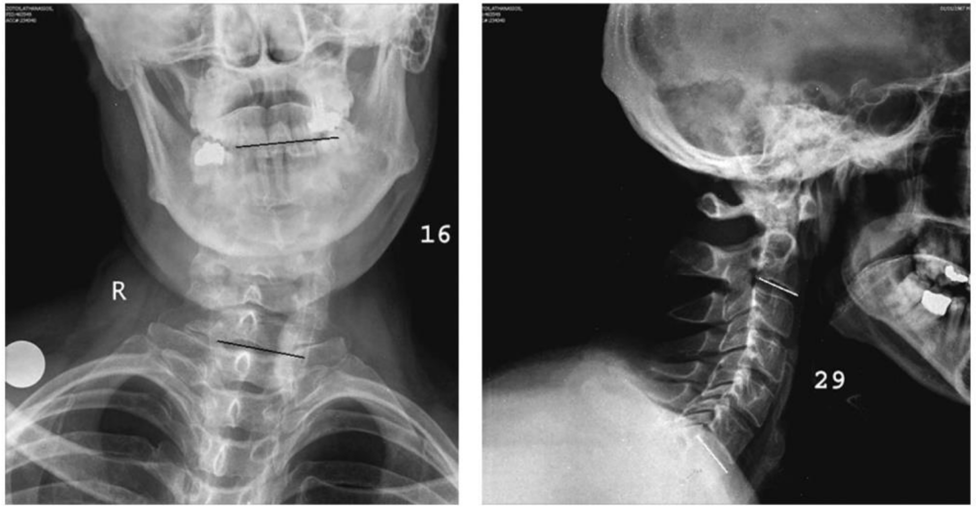


Figure 1.—Coronal and sagittal C2-C7 Cobb angle of a stroke patient before therapy and cervical isometric exercises.

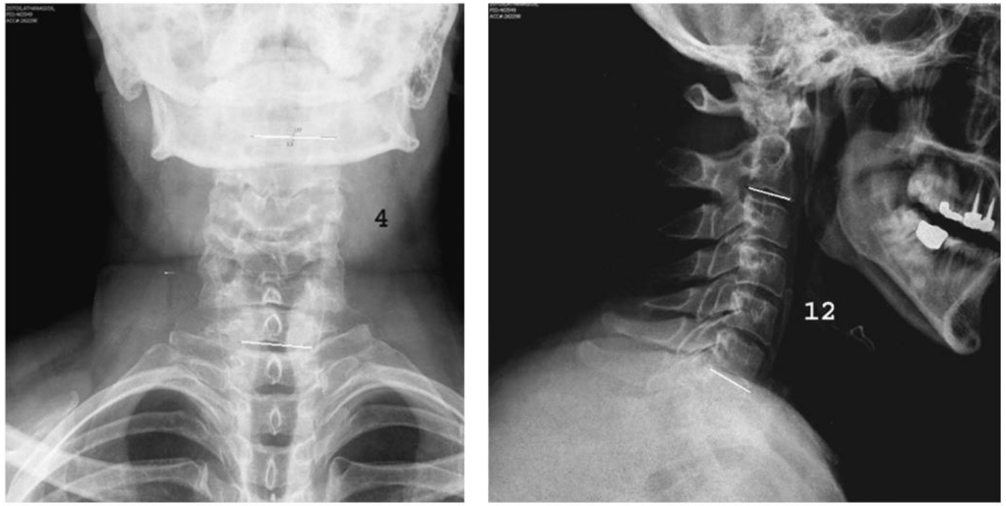


Figure 4.—Coronal and sagittal C2-C7 Cobb angle of the same patient of figure 2 at end of therapy which included cervical isometric exercises.

Alterations to Swallowing Physiology as the Result of Effortful Swallowing in Healthy Seniors

Sonja M. Molfenter[1] · Chuan-Ya Hsu[2] · Ying Lu[2] · Cathy L. Lazarus[3]

Dysphagia (2018) 33:380–388

- Pharyngeal constriction measurement: Normalized Maximal Pharyngeal Constriction Area (MPCAN)
- Pharyngeal shortening measurement

By Effortful swallowing
↓Laryngeal closure duration
↓ Hyoid movement duration
↓ UES opening duration
↓ Stage transition duration
↓ Pharyngeal transit time
↓ Pharyngeal response duration

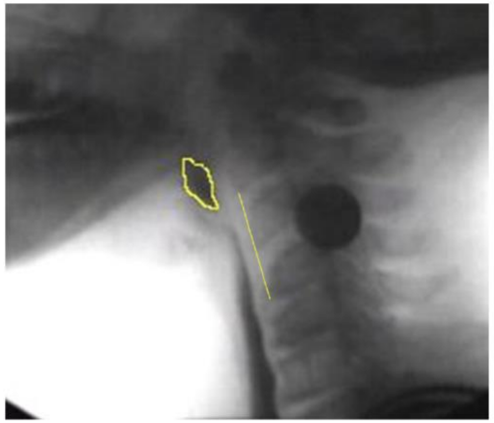


Fig. 1 Pharyngeal constriction measurement example. Pixels of unobliterated pharyngeal space at maximal pharyngeal constriction are expressed as a function of the C2-4 distance squared

Fig. 2 Pharyngeal shortening measurement example. Peak laryngeal position (point 3) from C4 (point 2) in a participant-defined coordinate system (*Y*-axis through points 1 and 2)

Table 6 Results of the comparison of regular effort and effortful swallows

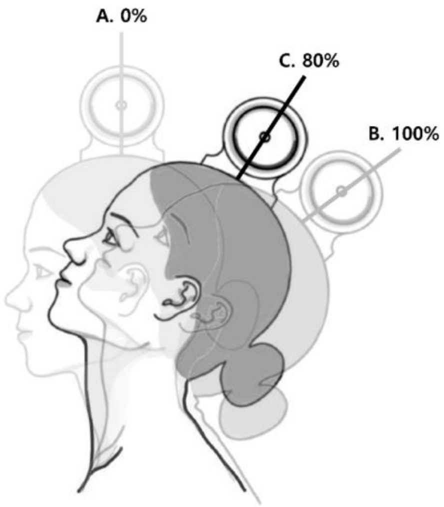
	Average treatment effect	SE	*p* value	Cohen's D
Kinematic measures				
Pharyngeal constriction ($MPCA_N$)	− 0.0005	0.0029	0.8900	–
Pharyngeal shortening (%c2-4)	− 2.629	1.0669	**0.0033**	0.29
Temporal measures				
Laryngeal closure duration (s)	0.3800	0.0543	**< 0.0001**	0.72
Hyoid movement duration (s)	0.5446	0.0676	**< 0.0001**	0.86
UES opening duration (s)	0.0739	0.0164	**< 0.0001**	0.53
Stage transition duration (s)	0.0687	0.0249	**< 0.0001**	0.27
Pharyngeal transit time (s)	0.1396	0.0285	**< 0.0001**	0.49
Pharyngeal response duration (s)	0.0713	0.0214	**0.0007**	0.39
Functional measures				
PAS	0.1214	0.0694	0.0713	–
NRRSv	0.0073	0.0068	0.2467	–
NRRSp	0.0072	0.0155	**0.0020**	0.02

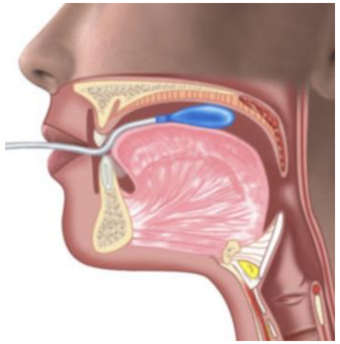
Bold values indicate significant at $p < 0.008$ threshold

Article

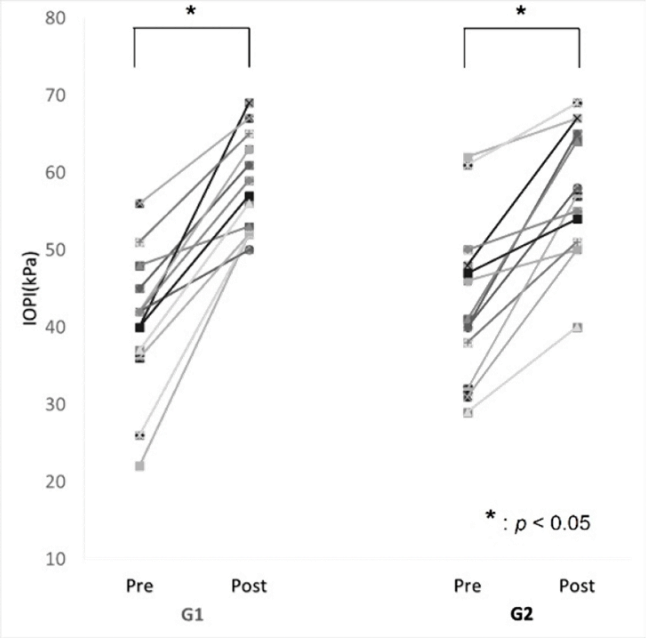
Effect of Progressive Head Extension Swallowing Exercise on Lingual Strength in the Elderly: A Randomized Controlled Trial

Jin-Woo Park *, Chi-Hoon Oh, Bo-Un Choi, Ho-Jin Hong, Joong-Hee Park, Tae-Yeon Kim and Yong-Jin Cho

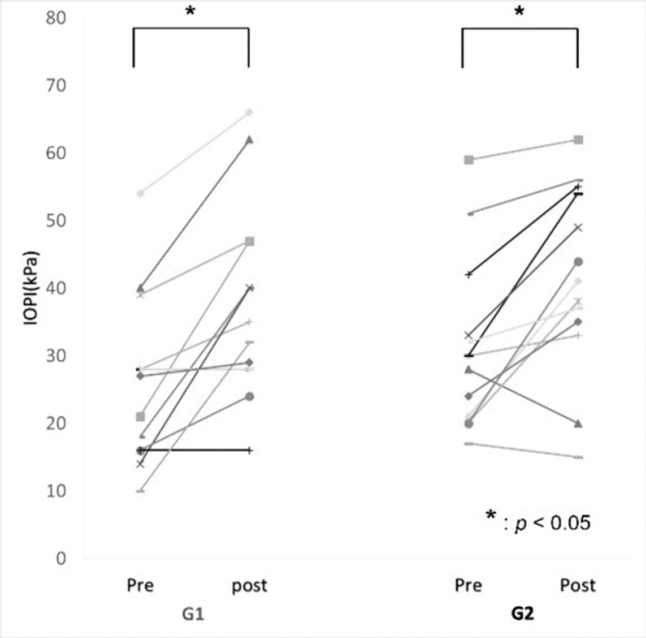




Maximum isometric pressure



Peak pressure during swallowing



- 80% head extension
- Effortful water swallow (2ml) every 10s
- 20min (10min + 5min rest + 10min)

- Iowa Oral Performance Instrument (IOPI)
- 1 set = 5 repetition (80% of 1RM, 3s holding) + 30s rest
- 24 set = Total 120 tasks

G1, tongue progressive resistance exercise group
G2, tongue isometric exercise group

J. Clin. Med. 2021, 10, 3419

Does Therapy With Biofeedback Improve Swallowing in Adults With Dysphagia? A Systematic Review and Meta-Analysis

Jacqueline K. Benfield, BSc (Hons), MSc,[a] Lisa F. Everton, BA (Sp & H Th) (Hons),[b] Philip M. Bath, FMedSci DSc,[b] Timothy J. England, MBChB, PhD, FRCP[a]

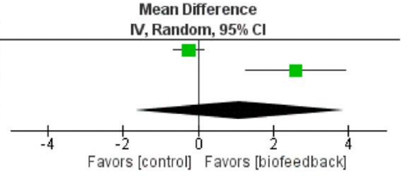
Dysphagia therapy augmented by biofeedback using sEMG and accelerometry enhances hyoid displacement but functional improvements in swallowing are not evident.

https://www.chattanoogarehab.com

A Functional Oral Intake Scale (FOIS)

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Aoki 2015	4.75	0.77	17	5	0.33	14	52.6%	-0.25 [-0.65, 0.15]
Li 2016	5.1	1.2	10	2.5	1.78	10	47.4%	2.60 [1.27, 3.93]
Total (95% CI)			**27**			**24**	**100.0%**	**1.10 [-1.69, 3.89]**

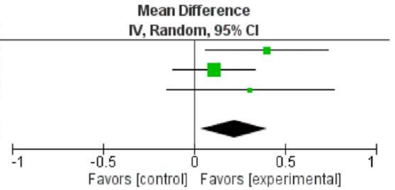
Heterogeneity: $\tau^2=3.81$; $\chi^2=16.13$, df=1 ($P<0.0001$); $I^2=94\%$
Test for overall effect: Z=0.77 ($P=0.44$)



B Hyoid displacement (cm)

Study or Subgroup	Experimental Mean	Experimental SD	Experimental Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Huimin 2015	1.3	0.6	17	0.9	0.4	19	27.5%	0.40 [0.06, 0.74]
Li 2016	1.45	0.26	10	1.34	0.25	10	57.1%	0.11 [-0.11, 0.33]
McCullough 2012 & 2013	1.99	0.72	17	1.68	0.64	17	15.4%	0.31 [-0.15, 0.77]
Total (95% CI)			**44**			**46**	**100.0%**	**0.22 [0.04, 0.40]**

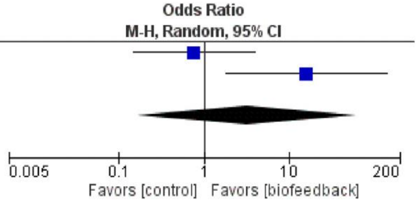
Heterogeneity: $\tau^2=0.00$; $\chi^2=2.17$, df=2 ($P=0.34$); $I^2=8\%$
Test for overall effect: Z=2.35 ($P=0.02$)



C Numbers with feeding tube removed

Study or Subgroup	Experimental Events	Experimental Total	Control Events	Control Total	Weight	Odds Ratio M-H, Random, 95% CI
Denk 1997	14	19	11	14	53.0%	0.76 [0.15, 3.92]
Li 2016	8	10	2	10	47.0%	16.00 [1.79, 143.15]
Total (95% CI)		**29**		**24**	**100.0%**	**3.19 [0.16, 62.72]**
Total events	22		13			

Heterogeneity: $\tau^2=3.66$; $\chi^2=4.76$, df=1 ($P=0.03$); $I^2=79\%$
Test for overall effect: Z=0.76 ($P=0.45$)



Archives of Physical Medicine and Rehabilitation 2019;100:551-61

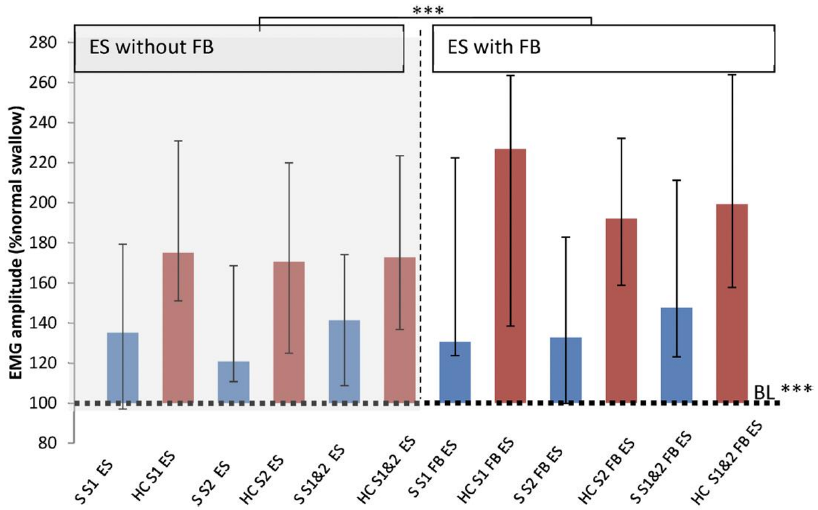
Surface Electromyographic Biofeedback and the Effortful Swallow Exercise for Stroke-Related Dysphagia and in Healthy Ageing

Sally K. Archer[1,2,3] · Christina H. Smith[4] · Di J. Newham[1]

Dysphagia (2021) 36:281–292

Fig. 1 Electrode placement. The two recording electrodes were positioned longitudinally on the anterior neck, mid-way between the mental spine of the mandible and the hyoid bone (attached to white wires), with the reference electrode to the side (attached to black wire). The self-adhesive electrode discs were then taped in place (Micropore, MidMeds, Waltham Abbey, UK; not shown)

Fig. 3 Effortful swallows (ES) with Feedback (FB) and without FB by stroke participants 'S' (n = 13) and healthy controls 'HC' (*n* = 17) for session 1 (S1) and 2 (S2) and for both combined (S1&2). Medians and IQR shown. Data is normalised to the normal swallow baseline (BL dotted line, i.e. 100%NS). There was a significant effect of task and FB with no effect of session. ***$p < 0.001$



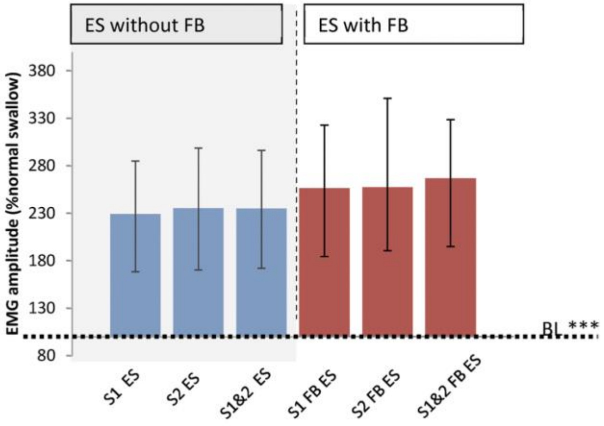


Fig. 4 Healthy participants effortful swallow (ES) amplitude (*n* = 82). Medians and inter-quartile ranges shown. Dotted line at 100% NS and *BL* = mean normalised normal swallow baseline. Asterisks on *BL* = significant difference between ES and normal swallow. There was a significant effect of FB (***$p < 0.001$) and no effect of session

Expiratory Muscle Strength Training

- Increasing the force generation capacity of the expiratory muscles (expiratory pressure (P_EMax) capacity)
- Improving pulmonary function in obstructive, restrictive pulmonary disease, and Parkinson's disease

Rule of fives

- 5 sets of 5 exhalations per session at 75% maximum expiratory pressure (P_EMax) capacity = 25 breaths per day
- 5 session per week
- 5-week time frame

Pressure threshold device

Am J Speech Lang Pathol. 2020 Feb 7;29(1):335-356

Effects of Expiratory Muscle Strength Training on Videofluoroscopic Measures of Swallowing: A Systematic Review

Renata Mancopes,[a,b] Sana Smaoui,[a,c] and Catriona M. Steele[a,c]

- Penetration-Aspiration Scale
  - Improvements in 5 studies
  - No change in 4 studies

- Engaging the submental suprahyoid musculature
- Longer durations and higher amplitudes during the muscle activation
- Facilitating hypolaryngeal excursion for airway protection and UES opening during swallowing

Authors	Statistical approach	Result for those receiving EMST
Pitts, Bolser, Rosenbek, et al. (2009)	Wilcoxon signed-ranks test	Significant improvement (p = .01)
Troche et al. (2010)	Repeated-measures analysis of covariance	Significant improvement ($p < .05$)
Hegland et al. (2016)	Repeated-measures analysis of variance	No significant change
Plowman et al. (2016)	Repeated-measures analysis of variance	No significant change
Park et al. (2016)	Wilcoxon signed-ranks test	Significant improvement ($p < .05$)
Eom et al. (2017)	Wilcoxon signed-ranks test	Significant improvement ($p < .05$)
Moon et al. (2017)	Wilcoxon signed-ranks test	Significant improvement ($p < .05$)
Silverman et al. (2017)	Frequencies for score range reported but not compared statistically	n/a
Hutcheson et al. (2018)	Nonparametric	No significant change
Plowman et al. (2019)	Chi-square	No significant change

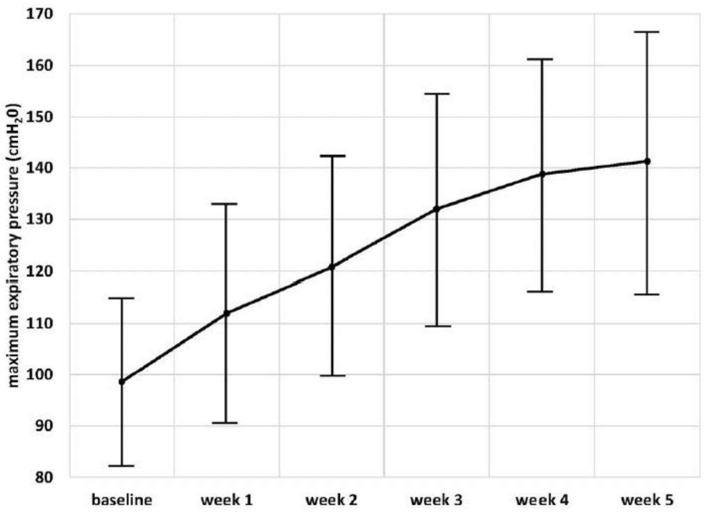
Note. EMST = expiratory muscle strength training; n/a = not app

Am J Speech Lang Pathol. 2020 Feb 7;29(1):335-356

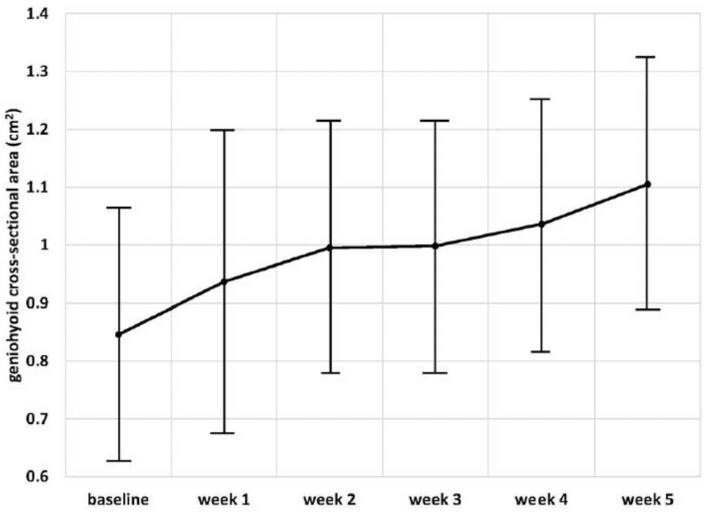
Using Ultrasound to Document the Effects of Expiratory Muscle Strength Training (EMST) on the Geniohyoid Muscle

Barbara R. Pauloski[1] · Kacey M. Yahnke[1,2,3]

- 10 healthy adults 21–57-year-old
- Protocol: Rule of fives at 75% P_EMax



Maximum Expiratory Pressure



Cross sectional area of geniohyoid muscle

Cross sectional area of geniohyoid muscle

Dysphagia (2021) https://doi.org/10.1007/s00455-021-10328-x

Evaluation of a non-personalized optopalatographic device for prospective use in functional post-stroke dysphagia therapy

Christoph Wagner, Lydia Stappenbeck, Harald Wenzel, Peter Steiner, Bernhard Lehnert and Peter Birkholz

Fig. 1. Illustration of three exemplary dynamic exercises used in functional dysphagia therapy [9]. Left to right: "Cleaning" of the cheek pouch, elevating the tongue tip, and swiping the tongue across the upper frontal teeth row. Black arrows depict tongue motion.

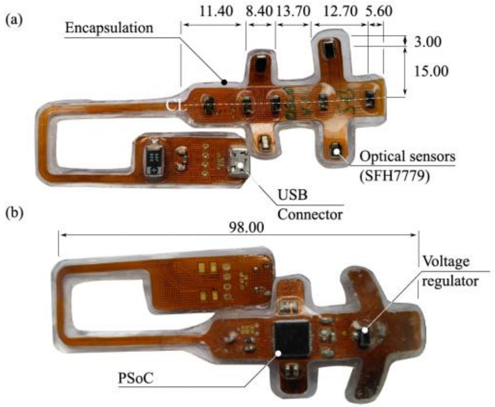


Fig. 2. Display of the device. (a) front view, showing the optical sensors and the dimensions (in millimeter), (b) back view, showing the PSoC control chip and the voltage regulator. The USB connector is bent inwards solely to save space and thus cost on the printed circuit board.

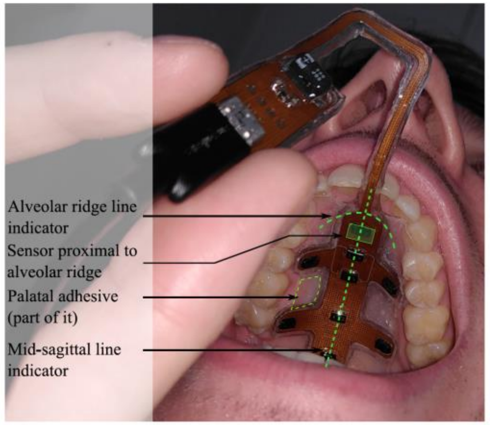


Fig. 4. Example of the device placed against the hard palate. Highlighted are the first optical sensor close to the alveolar ridge and the mid-sagittal alignment.

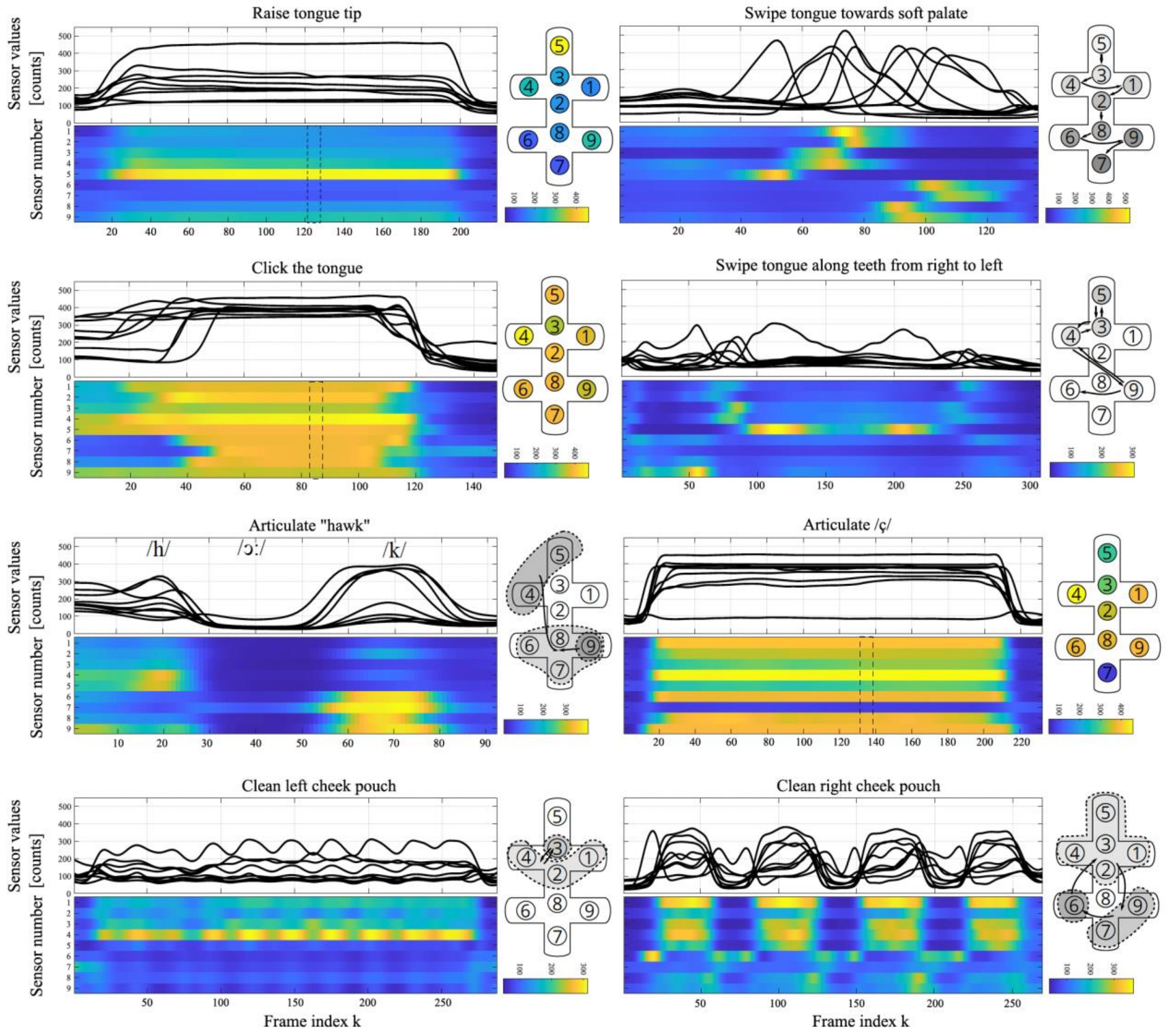
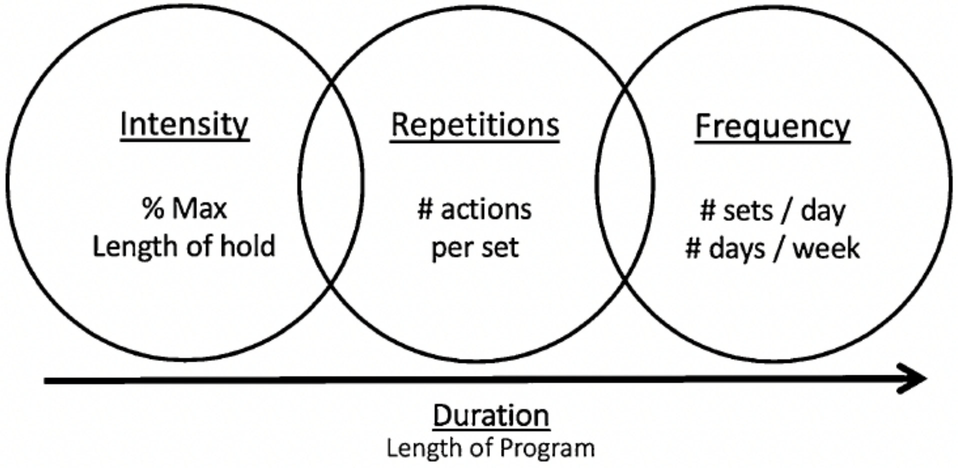


Fig. 5. Prototypical sensor readings for each (well executed) exercise as superimposed trajectories for all channels over time (upper part) and as a surface plot, showing each channel over time with the color-encoded ADC values (lower part). Illustrated right next to each plot are the sensor activations as seen in the direction from the device to the tongue (top down) and for the frames within the dashed box.

Dose of exercise

Dose in Exercise-Based Dysphagia Therapies: A Scoping Review

Brittany N. Krekeler[1,2,3] · Linda M. Rowe[1,2] · Nadine P. Connor[1,2]



- Recommendations varied greatly by exercise type.
- Further research is required to determine optimal dose ranges for the wide variety of exercise-based dysphagia interventions

GS (*)	Name of program	Frequency	Repetitions	Intensity	Duration	1st author (year) Citation number	Population(s) studied	Primary outcome(s)	p value(s)
*	Chin tuck against resistance (CTAR)	1 ×/day 5 days/week + "30 min/day conventional dysphagia treatment"	Isometric = 3 × Isotonic = 30 ×	Isometric = 60 s hold Isotonic = consecutive repetitions	4 weeks	Park (2018) [83]	Stroke	Oral, laryngeal elevation/epiglottic closure, residue	$p < 0.05$
*	TheraBite	3 ×/day 7 days/week	See publication for detail	See publication for detail	During CRT up to 1 year after	Molen (2014) [84]	Head and neck cancer	Weight gain, other outcomes	$p = 0.002$ Weight Gain
*	CTAR + JOAR		Isokinetic: 30 × consecutively, 1 s per contraction Isometric: maintained for 60 s, rest for 60 s, × 3 sets Effortful Swallow: (after 60 s rest) 10 ×	CTAR + JOAR: bar pressed to chin Effortful swallow: bar pressed to chin 50% Start intensity individualized based on dynamometry and 30 s max. Subsequent increase by self-perceived effort	6 weeks	Kraaijenga (2015) [85]	Healthy senior subjects	Chin tuck strength Jaw opening strength Anterior and posterior tongue strength Muscle volume Videofluoroscopy parameters	$p = 0.005$ $p = 0.005$ $p = 0.016$ and 0.08 $p = 0.008$ $p =$ not significant

Table 8 Exercise recommendations. Adapted from the American College of Sports Medicine and other sources

Type of exercise	Definition	Frequency	Repetitions	Intensity	Duration
Resistance exercise	Exercises that involve concentric and eccentric muscular contraction with the goal of improve muscular strength and power	2–4 ×/day; 2–3 × days/week	8–12 for most adults, 10–15 for middle-aged and older adults, 15–20 for improvement of muscular endurance (which may be of particular interest to the dysphagia clinician)	Novice to intermediate: 60–70% of 1-RM Experienced: ≥ 80% of 1-RM for experienced Older individuals: 40–50% 1-RM To improve muscular endurance: < 50% 1-RM Older individuals to improve power: 20–50% 1-RM	Specific duration of training has not been definitively determined according to these guidelines. However, a systematic review[a] of resistance exercise in older adults showed that most programs are between 8 and 12 weeks
Neuromotor exercise	Exercises that involve motor skills such as coordination and agility, which may be impaired in dysphagia from neural insult	20–30 min/day, 2–3 days/week	Repetitions, intensity, duration are not well defined for this type of treatment according to ACSM guidelines. However, there is a systematic review[b] that lists repetitions, intensity, and duration for studies included in their review that may be useful to reference. The overall conclusions of this study were not definitive due to varied findings and quality of evidence found during review of resistance-based neuromotor exercise. It is likely that consensus on this is difficult due to the wide range of neurological conditions that exist and the heterogeneity of individuals in the various disease categories, making this difficult to study		
Flexibility exercise (stretching)	Joint range of motion or flexibility	2–4 ×/each exercise, ≥ 2–3 days/week with daily being most effective	10–30 s static stretch time is recommended for most adults, 30–60 s for older adults,	Stretch to the point of slight discomfort (feeling muscle tightness)	Not specified

Table adapted from the American College of Sports Medicine's (ACSM) [118]

Patient Adherence to Dysphagia Recommendations: A Systematic Review

Brittany N. Krekeler[1,2] · Courtney K. Broadfoot[1,2] · Stephen Johnson[5] ·
Nadine P. Connor[1,2] · Nicole Rogus-Pulia[1,2,3,4]

Dysphagia (2018) 33:173–184

- ○ **Average adherence rate = 21.9 ~ 51.9%**
  - Exercise: 13 ~ 92% = average 43%
  - Food modification 36 ~ 67%

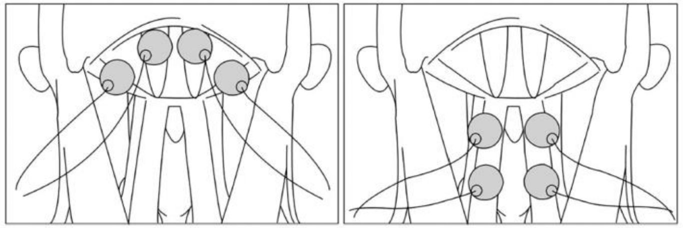
Author(s) year	Study population (*n*)	Age range (mean; ±)	Design (JAMA quality rating)	Recommendations	Adherence tracking	Adherence findings	Barriers/facilitators identified?
Leiter and Windsor (1996) [33]	Dysphagia, varied etiologies (*n* = 8)	69–80 (72)	Case series (4)	Swallowing recommendations (posturing, bolus size, swallow + cough, alternating food/liquid)	Observation	36% average adherence	Yes
Low et al. (2001) [17]	Dysphagia, varied etiologies (*n* = 140)	55–94 (77.4 and 79)[a]	Retrospective cohort (3)	Swallowing recommendations (modified foods/ liquids, techniques)	Self-report	67% adherent w/ swallow recommendation 84% adherent w/ liquid recommendations	Yes
Starmer et al. (2011) [27]	HNC (*n* = 118)	< 60 years	Retrospective cohort (3)	Participation in SLP therapy (before, during, after HNC tx)	Records reviewed	80% adherence (multidisciplinary) 17% adherence (outside referral)	No
Shinn et al. (2013) [24]	HNC (*n* = 19)	31–79 (57)	Prospective cohort (4)	Exercise	Documented by SLP	32% partially adherent 13% fully adherent	Yes
Hutcheson et al. (2013) [25]	HNC (*n* = 497)	38–80 (56)	Retrospective observational (3)	Exercise	Self-report	32% partially adherent 26% fully adherent	No
Duarte et al. (2013) [26]	HNC (*n* = 85)	22–91 (60)	Case series (4)	Exercise	Self-report	67% adherent	No
Shim et al. (2013) [34]	Dysphagia, varied etiologies (*n* = 62)	(64.1)	Retrospective chart review (3)	Thickeners	Self-report	57% adherence (90% of inpatients, 41% of outpatients) adherent	Yes
Cnossen et al. (2014) [28]	HNC (*n* = 33, 64% participated in exercise program)	21–77 (60)	Case series (4)	Exercise	Self-report	42% low adherence 30% moderate adherence 27% high adherence	Yes
Cnossen et al. (2016) [29]	HNC (*n* = 50)	40–77 (61)	Prospective cohort study (2)	Exercise	Self-report (diary)	70% adherence at 6 weeks 38% adherence at 12 weeks	No
Krisciunas et al. (2016) [31]	HNC (*n* = 153)	61.9 (± 9.6)	Randomized control trial (1)	Exercise + electrical stimulation	Self-report (checklist)	54% adherent	No
Wall et al. (2016) [32]	HNC (*n* = 71)	59.50 (± 6.15)	Randomized control trial (1)	Exercise (prophylactic)	Self-report (log-books), SwallowIT, clinician tracked	27% average adherence	Yes
Hajdú et al. (2017) [30]	HNC (*n* = 6)	42–67 (57)	Pilot study (4)	Exercise	Self-report (log-book, weekly phone calls)	92% average adherence	No

Electrical stimulation

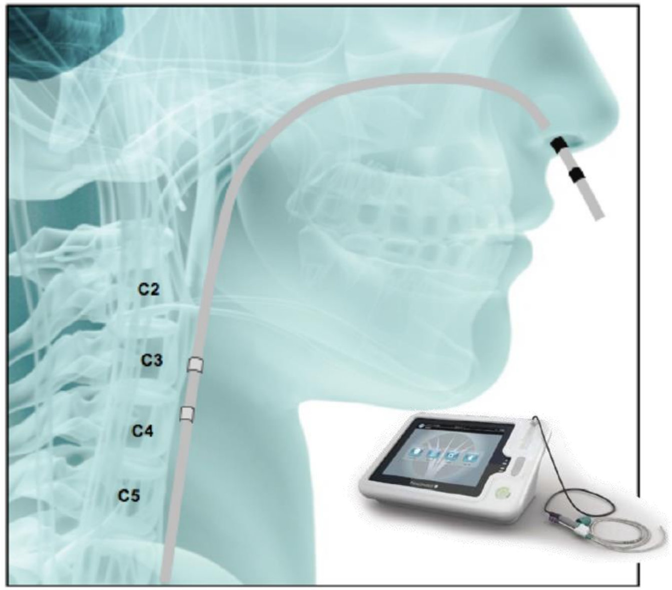
Target Muscle Actions	Possible Signs and Symptoms	Possible Electrode Placements
Oropharyngeal "sling" muscles	- Anterior spillage/leakage - Premature spillage residuals - Pocketing, holding, stasis - Nasal regurgitation	Placement over buccal branch of facial nerve - Maximum facilitation of synergists when electrodes applied bilaterally - Sensory input increased over cranial nerves V and VII
Tongue: bolus manipulation and tongue base retraction	- Decreased bolus propulsion - Premature spillage - Coating tongue base and/or posterior pharynx - Delayed swallow trigger - Vallecular pooling	Placement above the hyoid bone - May stimulate cranial nerve XII and facilitate tongue muscle recruitment Vertical placement above hyoid bone and over thyrohyoid muscle Horizontal placement above hyoid bone and over thyrohyoid muscle
Velopharyngeal seal	- Nasal regurgitation - Residuals - Delayed pharyngeal transit	Placement over buccal branch of facial nerve - Maximum facilitation of synergists when electrodes applied bilaterally
Hyolaryngeal excursion	- Decreased hyolaryngeal excursion - Penetration, aspiration - Voice abnormalities - Decreased UES opening - Pooling, residuals	Placement along midline over geniohyoid muscle belly - Facilitation of geniohyoid, mylohyoid and thyrohyoid muscles Vertical placement along midline - Facilitation of suprahyoid and infrahyoid muscles Vertical placement above hyoid bone and over thyrohyoid muscle - Facilitation of digastric and thyrohyoid muscles
Pharyngeal excursion	- Penetration, aspiration - Piecemeal deglutition - Residuals - Decreased pharyngeal transit time	Horizontal placement above hyoid bone and over thyrohyoid muscle - Electrode placements on attachments of middle (hyoid) and lower (thyroid) pharyngeal constrictors
UES seal opening and closing	- Delayed opening UES - Decreased opening UES - Premature closure UES - Penetration, aspiration - Pyriform pooling, residuals	Placement along midline over geniohyoid belly Vertical placement above hyoid bone and over thyrohyoid muscle - Focus on hyolaryngeal excursion Horizontal placement above hyoid bone and over thyrohyoid muscle - Focus on pharyngeal constriction

UES, upper esophageal sphincter.

Am J Phys Med Rehabil 2020;99:487–494



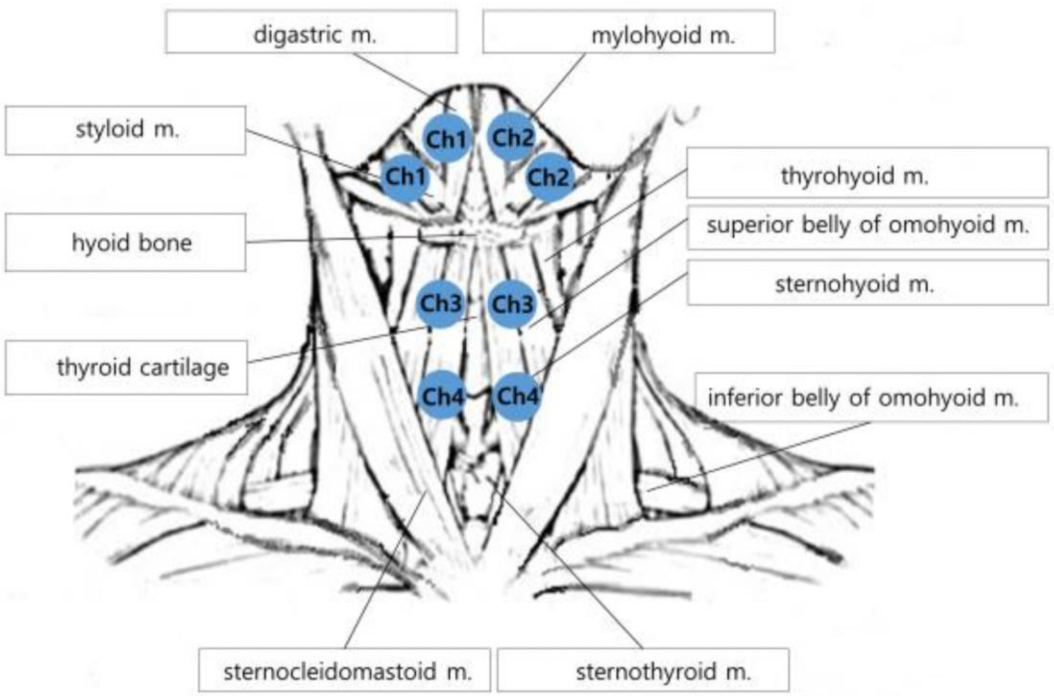
Journal of Back and Musculoskeletal Rehabilitation 33 (2020) 637–644

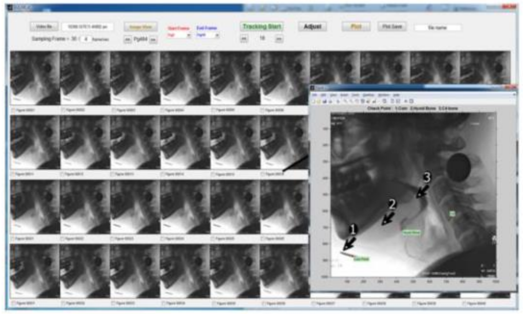


Medical Devices: Evidence and Research 2018:11 21-26

Compensatory Effects of Sequential 4-Channel Neuromuscular Electrical Stimulation for the Treatment of Acute, Subacute, and Chronic Dysphagia in a Prospective, Double-Blinded Randomized Clinical Trial

So Young Lee, MD, PhD[1], Donghwi Park, MD, PhD[2], Joonyoung Jang, MD[3], Eun Gyeong Jang, BS[3], Jun Chang Lee, PhD[3], Yulhyun Park, MD[3], Seon Cho, BS[3], Won-Seok Kim, MD, PhD[3], Jihong Park, MD[3], Bo Ryun Kim, MD, PhD[4], Kyoung-Ho Seo, MD, PhD[5], Sungwon Park, MD[6], and Ju Seok Ryu, MD, PhD[3]





- 4-Channel (n=26) vs. Sham (n=26)
- Suprahyoid, thyrohyoid, and other infrahyoid muscles during swallowing

- Stimulation procedure

: Channel 1, 2 stimulation → Channel 3, 150ms later
→ Channel 4, 250ms later

- VFSS

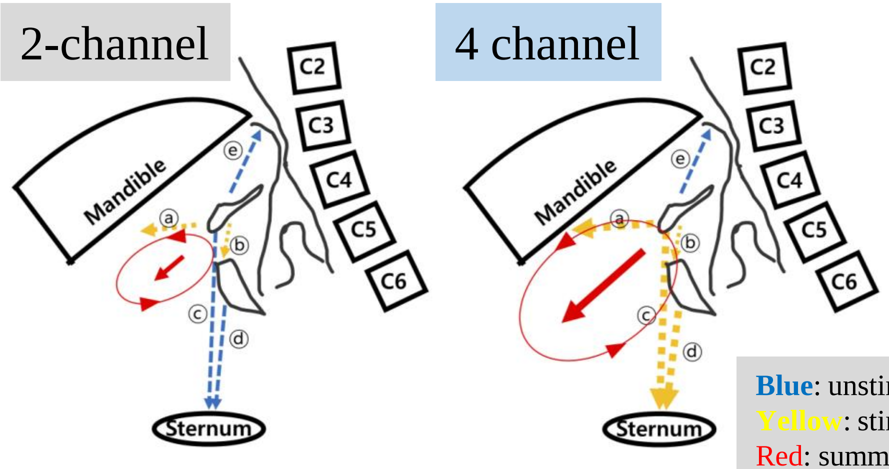
: T0 (initial), T1 (1week)
: Swallow under NMES or Sham stimulation

Neurorehabilitation and Neural Repair 2021, Vol. 35(9) 801–811

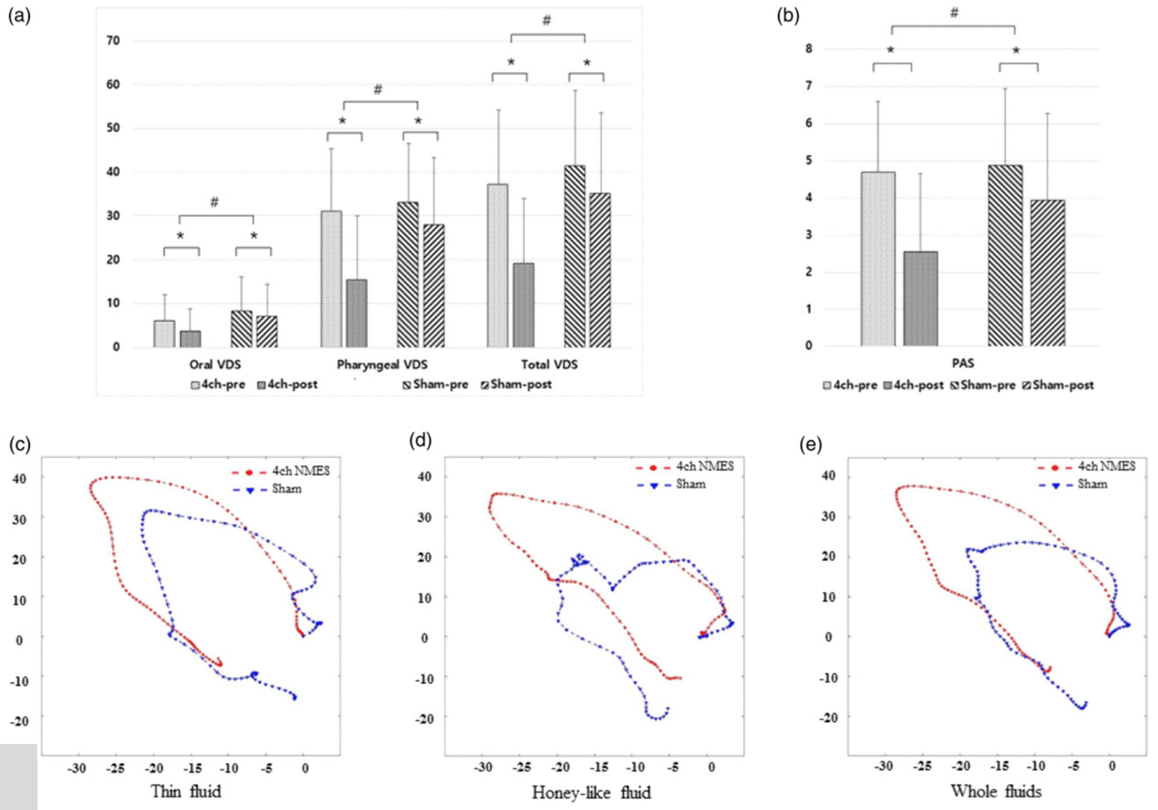
Compensatory Effects of Sequential 4-Channel Neuromuscular Electrical Stimulation for the Treatment of Acute, Subacute, and Chronic Dysphagia in a Prospective, Double-Blinded Randomized Clinical Trial

<u>4-Channel NMES *vs.* Sham</u>

Sequential 4-channel NMES showed significant clinical improvement with respect to videofluoroscopic dysphagia scale, penetration aspiration scale, and kinematic analysis.



Blue: unstimulated vectors
Yellow: stimulated vectors by NMES
Red: summated vector of stimulated vectors



Pharyngeal electrical stimulation for early decannulation in tracheotomised patients with neurogenic dysphagia after stroke (PHAST-TRAC): a prospective, single-blinded, randomised trial

*Rainer Dziewas, Rebecca Stellato, Ingeborg van der Tweel, Ernst Walther, Cornelius J Werner, Tobias Braun, Giuseppe Citerio, Mitja Jandl, Michael Friedrichs, Katja Nötzel, Milan R Vosko, Satish Mistry, Shaheen Hamdy, Susan McGowan, Tobias Warnecke, Paul Zwittag, Philip M Bath, on behalf of the PHAST-TRAC investigators**

	n	PES group*	Sham group	Odds ratio or median difference (95% CI)	p value
Primary outcome (randomised part of the study)					
Patients	69	35	34		
Ready for decannulation after PES or sham (primary outcome)		17 (49%)	3 (9%)	7·00 (2·41–19·88)	0·0008
Removal of the tracheal tube†		14 (82%)	1 (33%)	9·33 (0·62–139·57)	0·1404
Deflation of the tube-cuff†		3 (18%)	1 (33%)	0·43 (0·03–6·41)	0·5088

Medical Devices 2018:11 21-26

This study provides evidence that PES is effective in promoting earlier decannulation in patients with post-stroke dysphagia.

Lancet Neurol 2018; 17: 849–59

Hyoid Bone Movement at Rest by Peripheral Magnetic Stimulation of Suprahyoid Muscles in Normal Individuals

Hitoshi Kagaya, MD, DMSc*; Mao Ogawa, MD*; Shino Mori, MD, DMSc*;
Yoichiro Aoyagi, MD, PhD*; Seiko Shibata, MD, DMSc*;
Yoko Inamoto, SLHT, DMSc†; Hitoshi Mori, MS‡; Eiichi Saitoh, MD, DMSc*

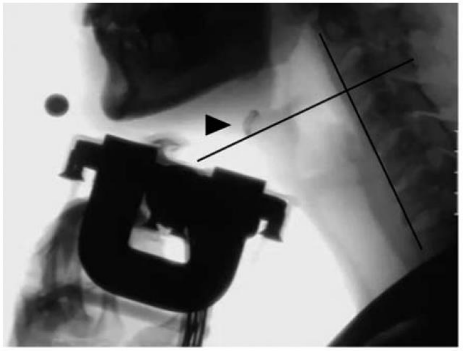
- 11 healthy subjects

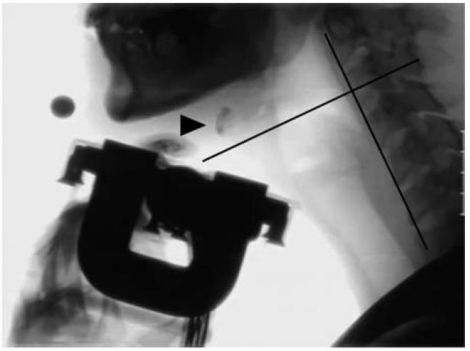
- Forward displacement ↑
- Upward displacement ↑

- Median NRS score during magnetic stimulation = 1

- Noninvasive and easy
- Not require skin preparation
- Minimum level of pain.

Figure 1. A specially designed coil was placed on the submental area of the subjects to stimulate the suprahyoid muscles. [Color figure can be viewed at wileyonlinelibrary.com]





off-stimulation on-stimulation

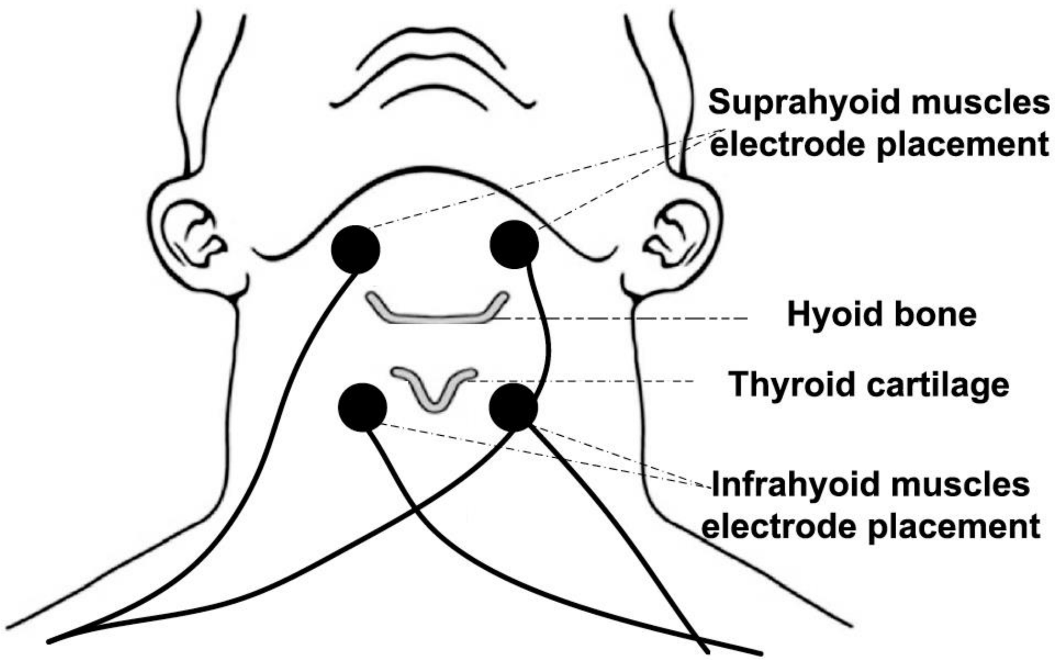
Neuromodulation 2019; 22: 593-596

Effects of Transcutaneous Neuromuscular Electrical Stimulation on Swallowing Disorders

A Systematic Review and Meta-Analysis

Yuanyuan Sun, MS, Xiaoyun Chen, MS, Jianhong Qiao, MS, Guixiang Song, BS, Yuedong Xu, BS, Yan Zhang, MS, Dongmei Xu, MS, Wei Gao, MS, Yunfeng Li, MS, and Cuiping Xu, PhD

Compared with traditional therapy



There is no firm evidence to conclude on the efficacy of neuromuscular electrical stimulation on swallowing disorders.

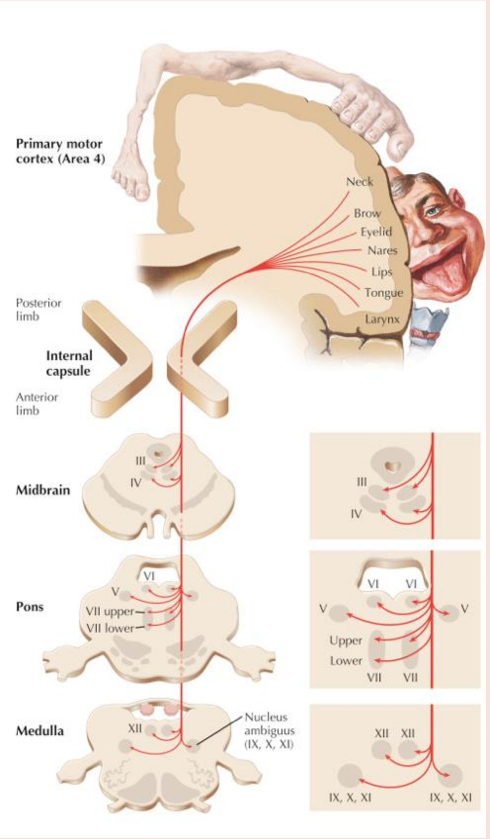
❑ Overall effects
: Moderate effect size
: Standard mean difference (SMD) = 0.62; 95% CI = 0.06 to 1.17

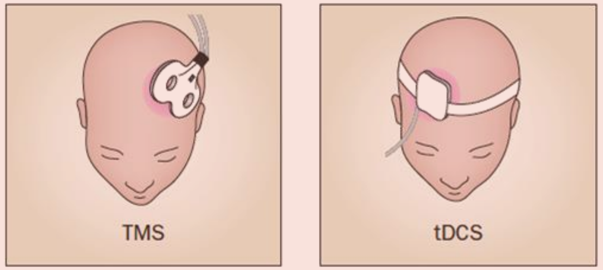
❑ Stimulation muscle
- Suprahyoid muscles
: Negative SMD = 0.17; 95% CI = −0.42, 0.08
- Infrahyoid muscles
: Large effect size
: SMD = 0.89; 95% CI 0.47, 1.30
- Supra + Infrahyoid muscle
: Large effect size
: SMD = 1.4; 95% = 1.07, 1.74

❑ Stimulation duration
- 45 mins or less
: Large effect size
: SMD = 0.89; 95% CI 0.58, 1.20

Am J Phys Med Rehabil. 2020 Aug;99(8):701-711.

Neuromodulation



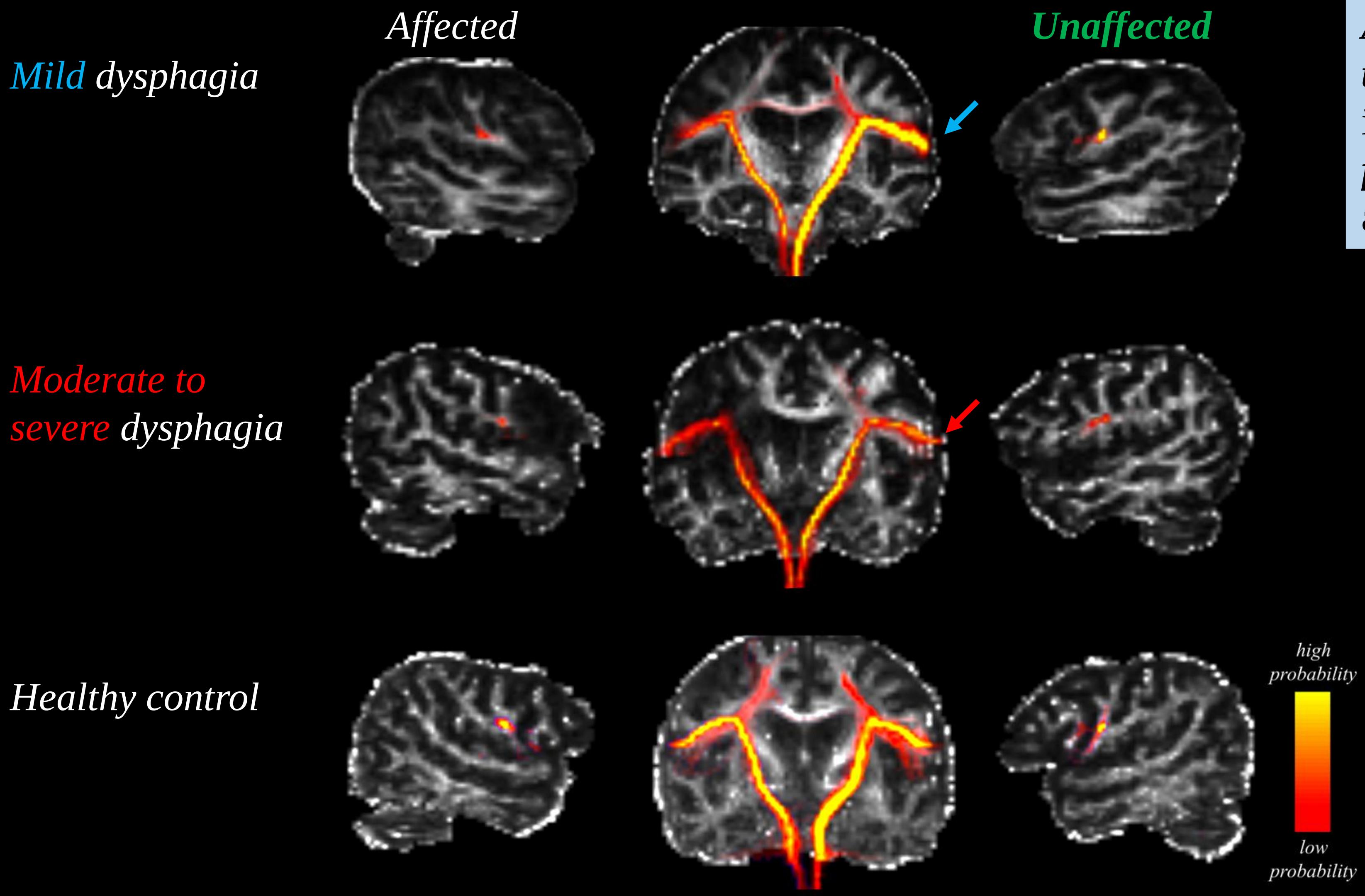


These unique features make the undamaged swallowing cortex an attractive target to facilitate dysphagia recovery.

- Dysphagia seems to recover more readily than dysfunction in other systems in the brain, which could be potentially explained by its bihemispheric control.
- The swallowing cortices do not exhibit transcallosal inhibition and appear to use their bihemispheric organization to provide a redundancy for a system that is already able to innervate swallowing nuclei on both sides of the brainstem using only one hemisphere.

Ann Neurol. 2018 Apr;83(4):658-660

Bihemispheric Organization for Swallowing



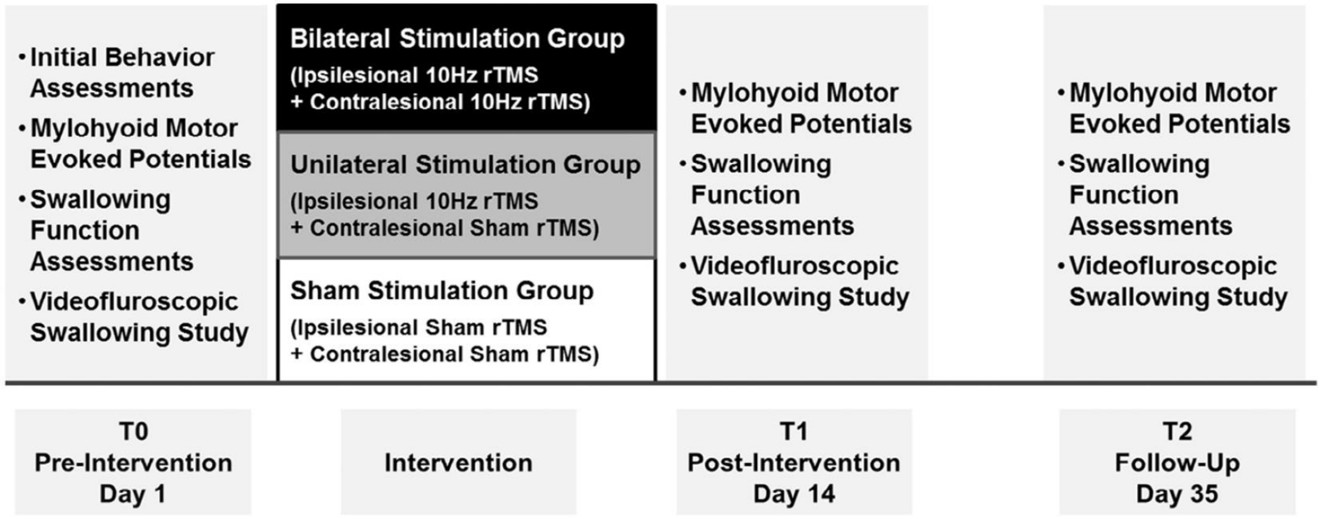
A higher corticobulbar TV in the unaffected hemisphere was indicative of ***better swallowing function*** in dysphagic patients after MCA stroke.

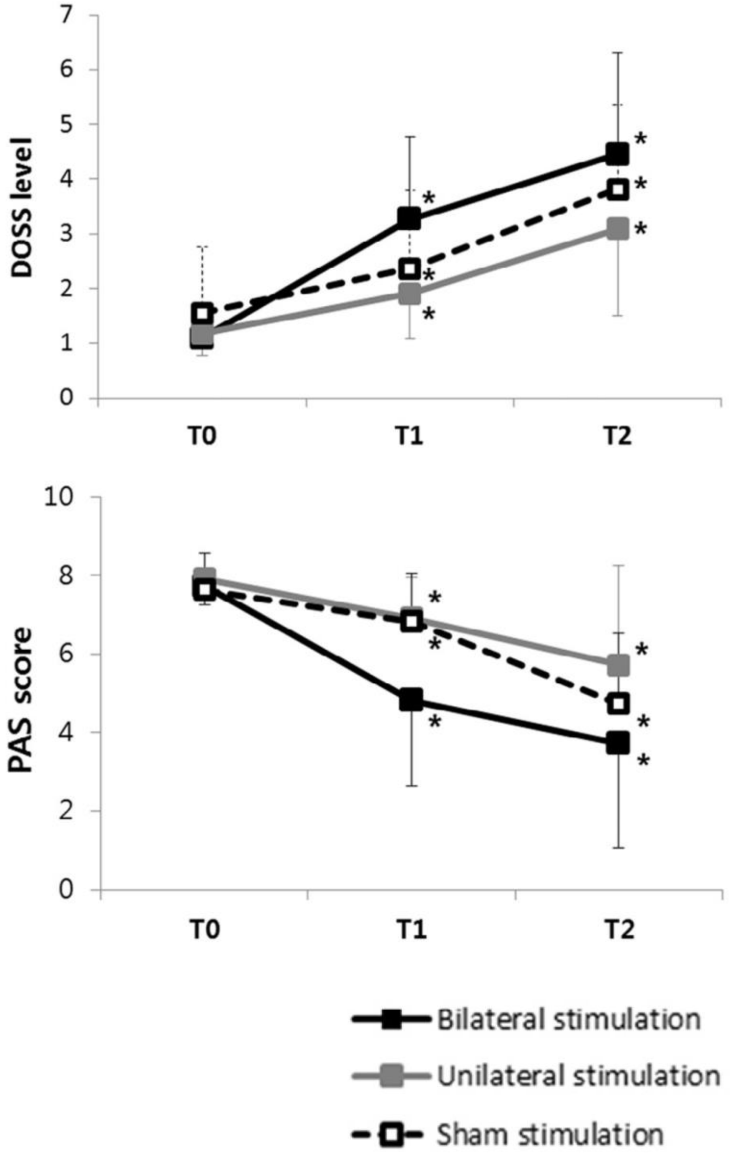
Im S et al. Eur J Neurol. 2020 Nov;27(11):2158-2167

Effects of Bilateral Repetitive Transcranial Magnetic Stimulation on Post-Stroke Dysphagia

Eunhee Park [a], Min Su Kim [b], Won Hyuk Chang [a], Su Mi Oh [a], Yun Kwan Kim [c], Ahee Lee [d], Yun-Hee Kim [a,c,d,*]

Comparison between
- Bilateral 10Hz rTMS
- Ipsilesional 10Hz rTMS + Contralesional Sham rTMS
- Bilatateral Sham rTMS



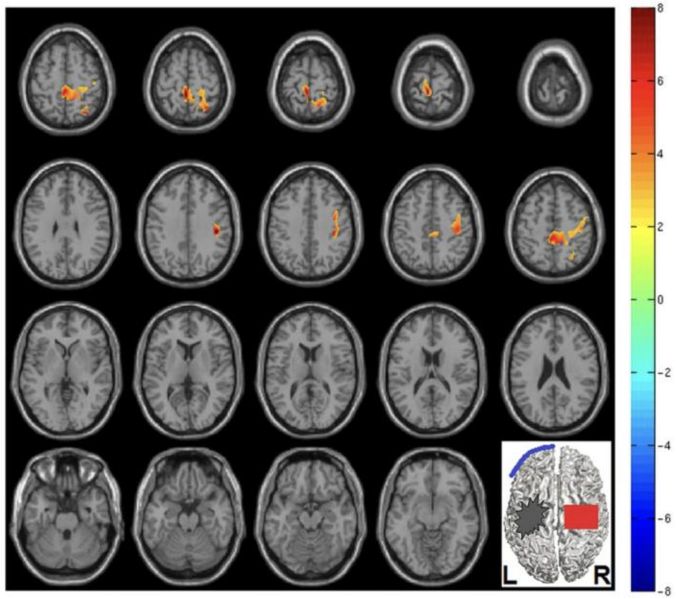


Brain Stimulation 10 (2017) 75–82

Randomized Trial of Transcranial Direct Current Stimulation for Poststroke Dysphagia

Sonja Suntrup-Krueger, MD,[1,2] Corinna Ringmaier,[3] Paul Muhle, MD,[1,2]
Andreas Wollbrink,[2] Andre Kemmling, MD,[4] Uta Hanning, MD,[5]
Inga Claus, MD,[1] Tobias Warnecke, MD,[1] Inga Teismann, MD,[1]
Christo Pantev, PhD,[2] and Rainer Dziewas, MD[1]

ANN NEUROL 2018;83:328–340

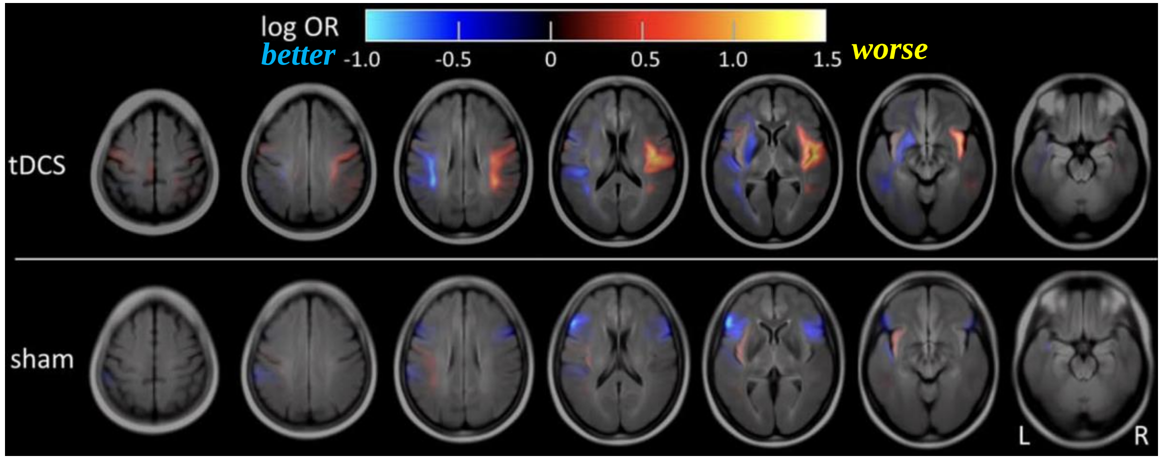


*Lesioned hemispheres were aligned to left side

Areas with significant increase of swallow-related event-related desynchronization after tDCS stimulation
- Primary and secondary sensorimotor cortex
- Supramarginal gyrus Dorsolateral prefrontal cortex
- Posterior cingulate.

Contralesional anodal (1mA, 20 minutes) vs. Sham tDCS on 4 consecutive days.

- Application of tDCS over the contralesional swallowing motor cortex supports swallowing network reorganization
- Early treatment initiation seems beneficial.
- tDCS may be less effective in right-hemispheric insulo-opercular stroke.



Lesion locations associated with negative treatment response in the tDCS group
: Right-hemispheric opercular cortex, superior longitudinal fasciculus, and insula (log OR>1)

Comparative Efficacy of Noninvasive Neurostimulation Therapies for Acute and Subacute Poststroke Dysphagia: A Systematic Review and Network Meta-analysis

Ching-Fang Chiang, MD,[a] Meng-Ting Lin, MD,[a] Ming-Yen Hsiao, MD,[a] Yi-Chun Yeh, PhD,[b] Yun-Chieh Liang, MS,[c] Tyng-Guey Wang, MD[a]

Facilitation ▪ High frequency ▪ Anodal	**Affected hemisphere** ▪ Structural reserve
Inhibition ▪ Low frequency ▪ Cathodal	**Unaffected hemisphere** ▪ Compensatory ▪ Interhemispheric inhibition

Table 1 Summary: the characteristics of included studies

Reference	Intervention	Inclusion Criteria	Protocol of Stimulation	Site of Stimulation	Comparison	Number	Stroke Type	Age (Year) Mean ± SD	Days After Onset Mean ± SD	Primary Outcome	Poststimulation Follow-up Time	Adverse Effect
Kumar et al[50]	tDCS	1. Onset 1-7 d 2. Dysphagia	2 mA anodal, 30 min/d, 5 d	Unaffected swallowing sensorimotor cortex	tDCS+ST vs sham+ST	7/7	Unilateral hemispheric infarction	79.7±10.2/ 70±11.9	3.3±1.8/ 4.0±1.9	DOSS	1 wk	No complication
Yang et al[48]	tDCS	1. Onset <2 mo 2. Clinical diagnosis of dysphagia	1 mA anodal, 20 min/d, 10 d	Affected pharyngeal motor cortex	tDCS+ST vs sham+ST	9/ 7	Unilateral hemispheric infarction	70.4±12.6/ 70.6±8.5	25.2±11.5/ 26.9±7.8	FDS	2 wk	No complication
Shigematsu et al[49]	tDCS	1. Onset >1 mo 2. Need for tube feeding	1 mA anodal, 20 min/d, 10 d	Affected pharyngeal motor cortex	tDCS+ST vs sham+ST	10/ 10	Any stroke	66.9±6.3/ 64.7±8.9	90/ 84	DOSS	2 wk	No complication
Suntrup-Krueger et al[56]	tDCS	1. Onset >24 h 2. Age ≥18 y 3. Dysphagia confirmed by FEES	1 mA anodal, 20 min/d, 4 d	Unaffected swallowing motor cortex	tDCS+ST vs sham+ST	29/ 30	Ischemic stroke	68.9±11.5/ 67.2±14.5	4.8±4.1/ 4.9±2.7	FEDSS	1 wk	No complication
Khedr et al[47]	rTMS	1. Onset 5-10 d 2. Clinical diagnosis of dysphagia	3 Hz at 120% RMT, 300 pulses, 10 min/d, 5 d	Affected esophageal motor cortex	rTMS vs sham	14/ 12	Unilateral cortical or subcortical infarction	58.9±11.7/ 56.2±13.4	5-10	DG	1 wk	No complication
Khedr et al[13] (A)	rTMS	1. Onset <3 mo 2. DG grade III-IV	3 Hz at 130% RMT, 300 pulses, 10 min/d, 5 d	Bilateral esophageal motor cortex	rTMS vs sham	6/ 5	Lateral medullary syndrome	56.7±16/ 58±17.5	42±29.1/ 38.5±1.4	DG	1 wk	No complication
Khedr et al[13] (B)	rTMS	1. Onset <3 mo 2. DG grade III-IV	3 Hz at 130% RMT, 300 pulses, 10 min/d, 5 d	Bilateral esophageal motor cortex	rTMS vs sham	5/ 6	Other brainstem infarction	55.4±9.7/ 60.5±11	22.4±5.6/ 25.9±5.6	DG	1 wk	No complication
Park et al[46]	rTMS	1. Onset >1 mo 2. Dysphagia confirmed by VFSS	5 Hz at 90% RMT, 500 pulses, 10 min/d, 10 d	Unaffected pharyngeal hot spot	rTMS vs sham	9/ 9	Unilateral hemispheric stroke	73.7±3.8/ 68.9±9.3	59.9±16.3/ 63.9±26.8	PAS	2 wk	No complication
Du et al[14]	rTMS (3 groups)	1. Onset <2 mo 2. Clinical diagnosis of dysphagia	3 Hz at 90% RMT or 1 Hz at 100% RMT, 1200 pulses, 5 d	3 Hz for affected hemisphere; 1 Hz for unaffected hemisphere	rTMS (3 Hz) vs rTMS (1 Hz) vs sham	15/13/12	Unilateral hemispheric infarction	58.2±2.8/ 57.9±2.5/ 58.8±3.4	8/6/9	SSA	1 wk	No complication
Park et al[12]	rTMS (3 groups)	1. Onset <3 mo 2. Dysphagia confirmed by VFSS	5 Hz at 90% RMT, 500 pulses, 10 min each side/ d, 10 d	Bilateral or unilateral (the affected) mylohyoid hot spot	rTMS (bilateral)+ ST vs rTMS (unilateral) + ST vs sham+ST	12/ 11/ 12	Unilateral hemispheric stroke	60.2±13.8/ 67.5±13.4/ 69.6±8.6	28.7±16.8/ 29.4±11.9/ 46.2±54.6	PAS	2 wk	No complication

Comparative Efficacy of Noninvasive Neurostimulation Therapies for Acute and Subacute Poststroke Dysphagia: A Systematic Review and Network Meta-analysis

Ching-Fang Chiang, MD,[a] Meng-Ting Lin, MD,[a] Ming-Yen Hsiao, MD,[a] Yi-Chun Yeh, PhD,[b] Yun-Chieh Liang, MS,[c] Tyng-Guey Wang, MD[a]

rTMS

In most of the studies included, high-frequency rTMS was used for either the affected hemisphere or the bilateral hemispheres to induce excitability of the corticobulbar projections to swallowing muscles.

Better outcomes for high-frequency over low-frequency groups and bilateral or unaffected side over affected side stimulation.

tDCS

All of the studies included used anodal stimulation on the affected or unaffected hemisphere for treating poststroke dysphagia.

tDCS of the unaffected cortex is postulated to increase pharyngeal representation in the sensorimotor cortex, which is thought to account for the recovery of swallowing function.

There is a larger proportion of affected side stimulation in the tDCS group, which may explain the less effective result of tDCS in this meta-analysis.

Archives of Physical Medicine and Rehabilitation 2019;100:739-50

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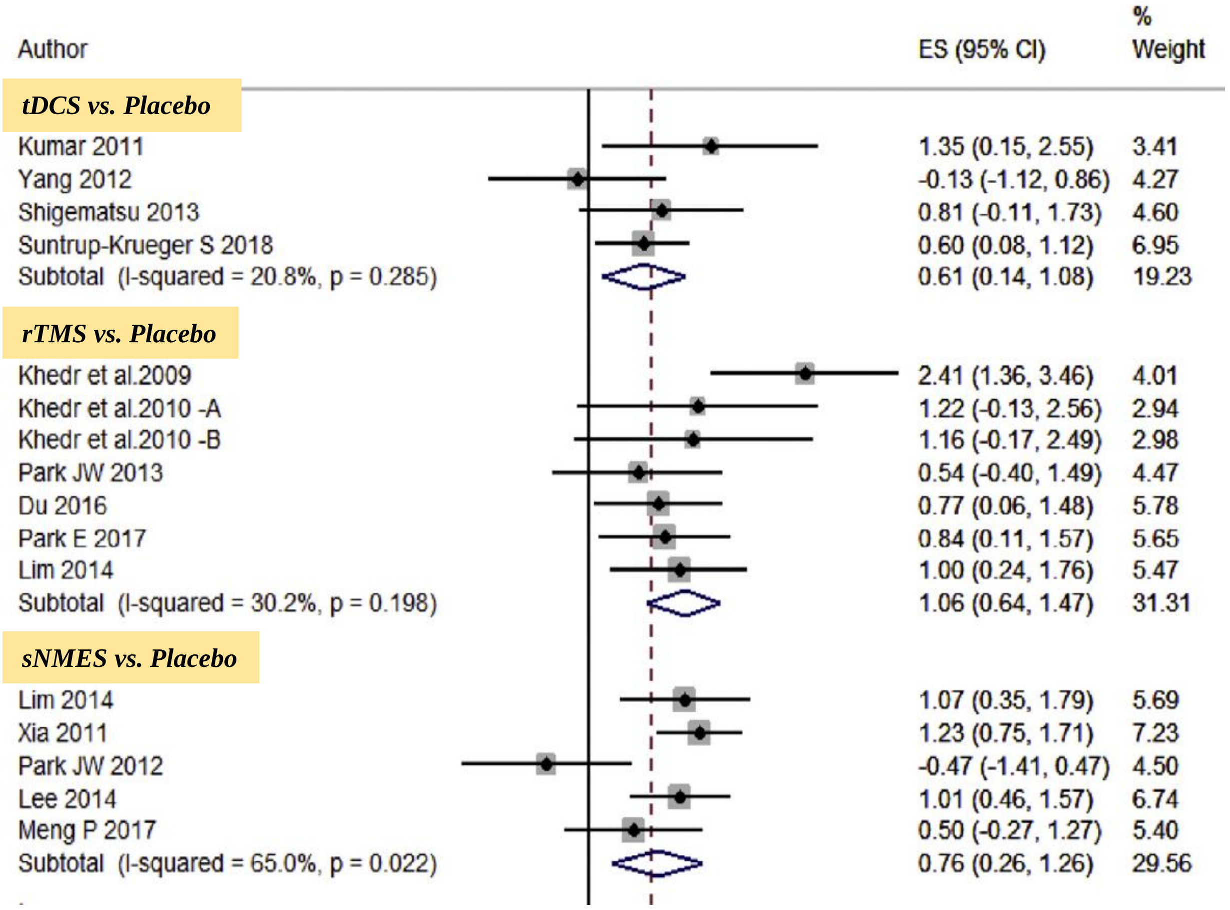
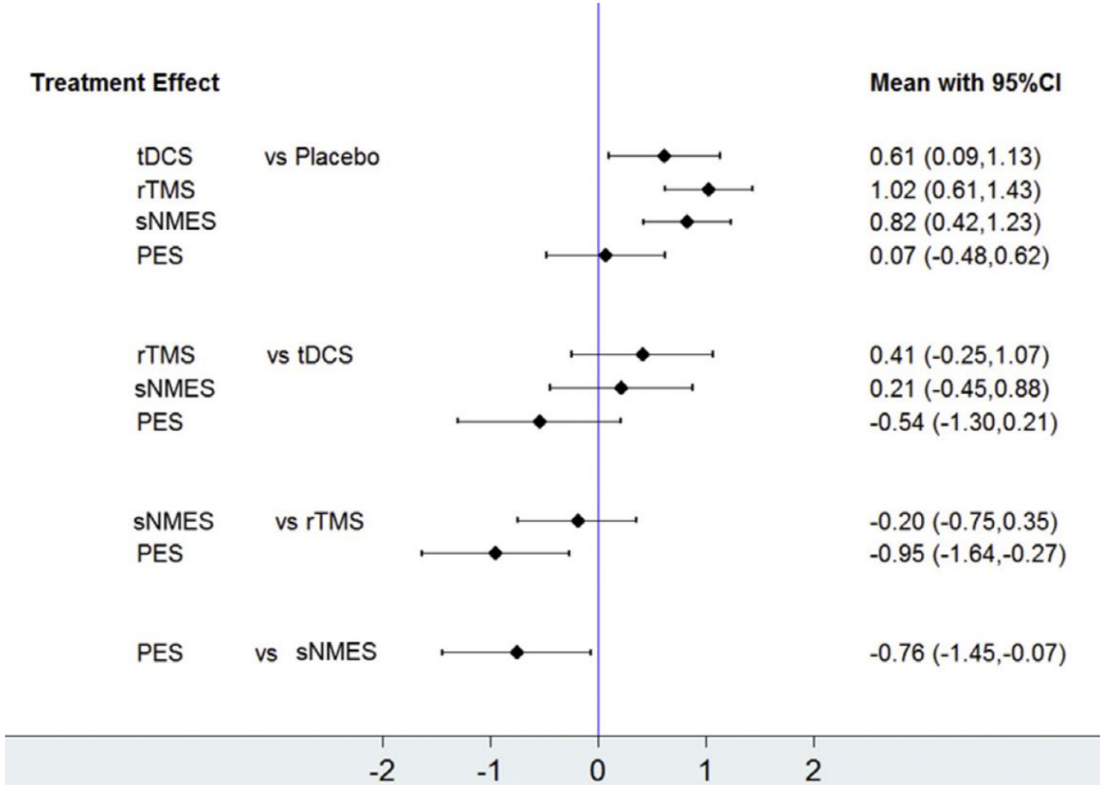


rTMS, tDCS, and surface NMES were effective for treating poststroke dysphagia.

Effect size: rTMS > surface NMES > tDCS



Archives of Physical Medicine and Rehabilitation 2019;100:739-50

Effects of Neurostimulation on Poststroke Dysphagia: A Synthesis of Current Evidence From Randomized Controlled Trials

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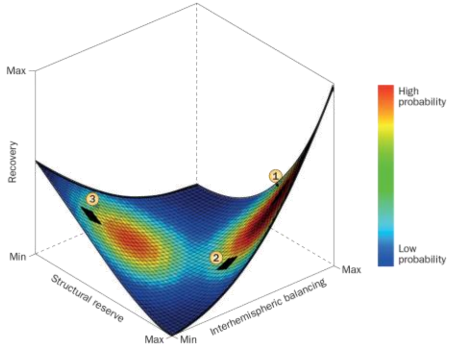

- ❑ Overall effects
  : 0.69; 95% CI = 0.50, 0.89
  - rTMS: 0.73 (largest effect); 95% CI = 0.49, 0.98
  - PES: 0.68; 95% CI = 0.22, 1.14
  - tDCS: 0.65; 95% CI = 0.25, 1.04

- ❑ Effect over time
  - Most significant within First 2 months (rTMS, tDCS, PES)
  - Lack of studies reporting long term outcome

- ❑ Based on Chronicity of stroke
  - < 2wks: rTMS ≈ tDCS ≈ PES
  - 3wks-2months: tDCS (largest effect)
  - > 3months: no report

- ❑ Based on Stimulation hemisphere
  - Bihemispheric stim: 0.93; 95% CI = 0.53, 1.33
  - Bihemispheric (> ipsilesional or contralesional)
  - Vicariation (compensatory reorganization of the unaffected hemisphere) *vs.* Interhemispheric competition *vs.* Bimodal balance-recovery model

- ❑ Based on Stimulation hemisphere and Frequency
  - Ipsilesional High-freq rTMS: 0.83, 95% CI = 0.14, 1.52
  - Contralesional Anodal tDCS: 1.04; 95% CI = 0.54, 1.53

Neuromodulation. 2020 Dec 10. doi: 10.1111/ner.13327.

Summary

Exercise

- Shaker exercise
- CTAR exercise
- Effortful swallowing
- Biofeedback
- EMST

Peripheral Electrical Stimulation

- NMES
- PES

Neuromodulation

- rTMS
- tDCS

Future researches are needed to shed light on

- ❑ Dose
  : *frequency, repetition, intensity*
- ❑ Adherence
- ❑ Electrode placement
  : according to *abnormal physiology*
- ❑ Mechanisms of action
  : *Bihemispheric control*
  : *One hemisphere innervates both sides of brain stem*
- ❑ Long-term outcome >3 months